H. J. Darvill. Lieut R.E.

INSULATION OF DEFENCE BUILDINGS

Construction of buildings for defence purposes tends to be divided into two types—one employing comparatively light permanent or semi-permanent construction, of steel or steel-and-timber framework, covered with thin corrugated sheets or similar ; the other of comparatively heavy construction embodying the use of reinforced concrete.

With many points of difference, these two have one point in common —low thermal resistance value which gives :—

(A) High capital costs for heating plant and high fuel costs in winter.
(B) Undue penetration of solar heat in summer.
(C) Liability to formation of condensation in cold weather.

These conditions are very simply overcome by the appropriate use of insulating fibre boards, as shown by the following figures for a corrugated asbestos roof on steel or timber framing.

	Unlined	Lined with ⅝" Tentest
Thermal Transmittance (expressed in B.T.U. per sq. feet per hour, per °F.).	1·40	0·31
Heat loss in B.T.U. per 1,000 sq. feet of roof surface, with 30° F. temperature difference	42,000	9,300
Superficial area in sq. feet of H.W. pipes or radiators required per 1,000 sq. feet of roof surface	263	58
Cost of heating plant at 5/- per sq. feet of radiation surface	£65.15.0	£14.10.0

These figures, by Dr. Oscar Faber, O.B.E., show that the saving in capital cost of heating plant more than covers the cost of insulation, apart from reduced fuel costs. Figures for many other constructions are available from The Tentest Company.

CONDENSATION

occurs where warm, moist air comes into contact with a surface having a temperature below the dew point of the air. Insulation, properly applied, eliminates condensation by raising the temperature of the internal surface above dew point. In an insulated building, far higher humidity is permissible without fear of condensation. In a building with an unlined concrete wall or roof 5 inches thick, internal temperature 74° F., and external temperature 30° F., condensation occurs when relative humidity rises above 47 per cent. whereas, if the wall be lined with ⅝" Tentest (no air space), relative humidity of 74 per cent. is permissible without condensation.

A NEW TECHNIQUE

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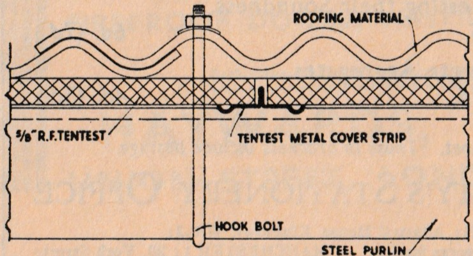

Full particulars of the figures mentioned above and specifications for application may be obtained without charge from

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MILITARY ENGINEERING

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DEFENCES

Part I.—LAND DEFENCE

CHAPTER I

INTRODUCTION

1. General principles

1. The history of fortification is a narrative of continuous and progressive contest in invention between offensive weapons and defensive materials and methods. Through all the phases of this contest may be traced the action of certain broad principles which govern the technique of the defensive art in all its manifestations.

2. This is not concerned with the principles which govern the strategical or tactical employment of the defensive. A consideration of these is to be found in Field Service Regulations, Vols. II and III, and it is not necessary to consider them here, except to the extent to which they influence engineering considerations. The principles which are referred to in para. 1, above, are those which govern the design of defensive works and the siting and lay-out of defensive positions, with special reference to those which have been deliberately prepared.

3. It may be assumed that the locality which has to be defended is one of strategic importance, so that the enemy is obliged to attack it or to abandon his strategic objectives, and, further, that it is either a position with secure flanks or is designed for an all-round defence until it is relieved by an external force, or until strategic action in another part of the theatre of war brings about the overthrow of the enemy. If the first of these conditions is not fulfilled, the necessity for defending the position is not likely to arise, since the enemy will either ignore it or will detach a small force to mask it and prevent the active intervention in his strategic plans of the force holding it. In such a case the labour expended in preparing it for defence will have been wasted. If the second

condition is not fulfilled, the position is liable to be turned, and the defenders are exposed to the danger of defeat by envelopment. In this case the defensive works will be not merely a waste of labour but a positive danger, since they form a strong temptation to the acceptance of battle under markedly unfavourable conditions.

4. Whatever may be the purpose of a commander in adopting a defensive role, the direct and immediate object of the force in occupation of a position deliberately prepared for defence is as under :—

i. To deny the enemy access to the locality defended for as long a period as the defender's resources in men, munitions and supplies admit.

ii. To perform this service with the utmost economy of force.

5. The prime conditions which every defensive position or work should fulfil to enable its defenders to achieve the above aims may be stated as follows :—

i. It should admit of the fullest possible development of the power of the weapons used by the defenders.

ii. Conversely, it should restrict to the greatest possible extent the use and effect of the weapons of the attackers.

6. These principles apply equally to all times and to all weapons. Their action may be traced in the Roman defences of the time of Cæsar and equally in the stupendous lines of trenchwork which grew up on the Western Front during the Great War.

2. Lessons and innovations of the Great War

1. The great fortresses or fortified areas which defended either side of the Franco-German border between Luxembourg and Switzerland were not subjected to attack during the opening phase of the Great War, although by their mere existence they appear to have profoundly affected the strategic developments, since it was no doubt owing to the delays which the fortresses on the French eastern frontier would have imposed on the German armies of invasion that the line of advance through Belgium was adopted. The fate of the Belgian fortresses of Liège, Namur and Antwerp in 1914, however, shows the weakness of nineteenth-century fortification against heavy artillery. At each of these three places the defences had recently been reconstructed. They consisted of a girdle of detached forts, each containing a number of guns in steel cupolas revolving or disappearing by machinery

and buried in a mass of concrete. Underneath were concrete chambers providing accommodation for the personnel, for the machinery required for lighting, ventilating, hoisting shell, etc., and for magazines for ammunition. Although the guns themselves in their cupolas were hidden, the works were generally quite conspicuous. Modern though these forts were, they had not been designed to meet even the lightest (21-cm. calibre) of the great weapons which were used against them and which also outranged their own guns. The effect of the heavy howitzers (21-cm., 28-cm. and 42-cm.) of the Germans was overwhelming. Armour plating was rent and demolished, cupolas were overturned, concrete chambers and magazines penetrated, and the whole structure reduced to ruins. In no case did a fort hold out for more than eight days from the first use of heavy artillery against it.

2. The only French fortress that was subjected to siege at the beginning of the war was Maubeuge. This fortress, being on the northern frontier, had not been remodelled like those on the eastern frontier; in fact it had been almost entirely neglected, and its works had no prospect whatever of resisting the artillery of the twentieth century. At the outbreak of the war the garrison was about 40,000 men, nearly all second-line troops ill trained for active operations. From the first day of mobilization the fortress commander employed every available man in constructing a system of field defences and wire obstacles, in providing light railways and telegraph communications and in collecting supplies. By 25th August the retirement of the French and British forces and the advance of the Germans had resulted in the isolation of Maubeuge. On 28th the heavy siege train, which included some 42-cm. howitzers, began to bombard the town and the eastern defences. The defence artillery, being entirely outranged, could make no reply. The obsolete permanent works were swiftly destroyed. On 31st the fortress commander organized a sortie in force with a view to silencing some of the besieging artillery but, though it was executed with energy and boldness, it did not succeed. On 3rd and 4th September German infantry attacks on the north-east front were repulsed, but on 5th the defenders began to be pressed back. By this time the defences on half the perimeter had been rendered useless. The battle continued on 6th and 7th, the defenders giving ground slowly until they had been pressed back almost to the walls of the town. On the afternoon of 7th the capitulation was signed, and on 8th the Germans occupied the town. This defence of eleven days from the beginning of the bombardment was carried out from permanent works, of which some dated from the eighteen-eighties and some from 1894, but it was the provisional defences in the intervals and the active

nature of the defence which caused a delay to the Germans longer than that caused by the modern steel and concrete forts of Liège and Namur.

3. Verdun was the most important of the chain of fortresses which, after the war of 1870, had been constructed for the defence of the French eastern frontier. It had been remodelled according to the latest ideas prevailing before the war, and the forts of its outer ring, some thirty miles in perimeter, had guns in steel disappearing cupolas, deep ditches with flanking galleries, strong concrete chambers, and casemates containing 77-mm. guns for the flank defences of intervals, and may be said to have represented the last word in permanent fortification on the French side. In the opening phase of the war the Germans refrained from a direct attack on the Verdun defences, but the Crown Prince's army endeavoured unsuccessfully to cut the communications of the fortress by an advance through the Argonne on to the Meuse. This respite gave the French an opportunity to take warning by the fate of the Belgian fortresses. During the winter of 1914-15 a new line of defence was established some miles beyond the outer line of forts. The new line consisted of a continuous system of trenches, organized in depth, with a strong line of wire obstacles and communication trenches. Its guns were in concealed positions well in rear of the infantry line, and communication roads for the service of ammunition and supplies were provided. The pre-war forts were dismantled and their armaments used in the new defensive system. When the campaign on the Western Front stabilized into position warfare, the Verdun position became a salient point in the Allied line.

The great German attack began on 21st February, 1916. It was launched in very great strength under cover of an extremely violent bombardment of pieces of all types, including the 42-cm. howitzer. The sector attacked was thinly held. After four days' heavy fighting the defenders had been pushed back a depth of about four miles. French reserves then began to arrive at Verdun, and, although the Germans redoubled the strength of their attacks and the fury of their bombardment, their progress was very slow, and only at enormous sacrifice of lives was each step accomplished. The attacks continued with little intermission throughout March, April, May and June, and came to an end when the Allied advance on the Somme drew off the German reserves. The defensive line had been pressed back till at one place it was within four miles of Verdun, but the city and railway junctions, which were the strategic objective of the attack, had been preserved.

During the operations the pre-war forts of Douaumont

and Vaux were the scenes of sustained and bitter fighting. Their armaments had been removed previously, and it does not appear that their defensive capacity, except for the great value of their shell-proof shelters, was appreciably greater than that of other parts of the defensive line, but, as they occupied points of great tactical value, special efforts were made and immense sacrifices incurred to gain them on the one hand and to retain them on the other. The equally valuable tactical position on Mort Homme Hill, which was defended by nothing but field trenches, resisted the German attacks for six weeks and exacted an even greater toll of lives before it fell.

4. The operations leading up to the stabilization of the line on the Western Front from the sea to Switzerland and the whole of the trench warfare operations which followed on this afforded ample proof of the high defensive power of an improvised system of trenches and barbed wire held by modern rifles and machine guns. A properly organized position of this type, if its flanks were secure, was found to be capable of resisting the strongest attacks, even after subjection to heavy bombardment by artillery. This phenomenon of the apparent impregnability of this type of defensive position manifested itself not only in the Western Front, but in all the theatres of war. For some time it appeared as if the material resources of the world were inadequate to provide a solution of the problem, and that the machine gun and barbed wire had permanently secured the position of mastery in the age-long contest between the methods and materials of the defence and the methods and weapons of the attack.

Immense masses of artillery were employed in preparations for attack. The objects were :—

i. To destroy the trenches and overwhelm their occupants so that they should be incapable of resistance.
ii. To destroy the wire entanglements impeding the advance.
iii. To form a curtain behind the defenders' front line in order to prevent reinforcements from reaching it, and to guard against counter-attack.
iv. To neutralize the rapid-fire weapons of the defence at the moment of assault by a creeping barrage.

The provision of mined dug-outs, deep enough below the ground to be secure against the heaviest shells, was the defence adopted against bombardment. The attack then developed the system of providing an artillery barrage of shrapnel immediately in front of the attacking line of infantry and moving forward with it, the object being to force the defenders to

remain in their dug-outs until the attackers arrived in the trench and sealed the entrances.

The defect of the deep dug-out was that the defenders were often unable to reach their fire positions in time to use their weapons. The counter-defence ultimately evolved to this moving barrage was the more effective organization of the defensive systems in depth and the use of reinforced concrete shelters in place of deep dug-outs. Instead of successive lines of trench, the defence was organized in small posts arranged roughly chequerwise and supporting each other by fire.

The concrete "pill-box" system, which held up many attacks in 1917, was the most successful manifestation of the system of small posts. These "pill-boxes," besides being a defence against the moving barrage, were also a good defence against the preliminary bombardment. Their construction was strong enough to resist a direct hit by shells up to 6-inch, and their small size and the skill with which they were concealed made them most difficult to hit with larger-sized shells.

Experience showed that the employment of heavy artillery in great masses as a preparation for attack can be carried to the pitch of so breaking up the ground by shell craters that the advance of the attacking infantry may be seriously hampered. This is particularly the case when the soil is wet or the ground is low-lying ; the disturbance of the natural drainage channels may result in areas of almost impassable swamp.

5. When a state of deadlock had been reached in which it seemed impossible to overcome the defensive power of the combination of the machine gun with barbed wire, it was natural that endeavours should be made to produce a contrivance which, while invulnerable to the former, should be able to force a passage through the latter. The tank, given suitable conditions, proved itself capable of achieving this purpose, and undoubtedly did more towards solving the problem than any of the other weapons that the War developed or produced.

3. Modern developments and their implications

1. Recent military developments have all been in the direction of increased fire power and greater mobility. They have been brought about chiefly by the progress of what is termed "mechanization," which carries with it a growing dependence of warfare on industry and science. The military machine is increasing in power and range, but at the same time it is becoming more complicated and more costly. The

general trend is in consequence to smaller, though harder hitting, armies. This being so, we may expect that in the initial stages of a conflict victory will be sought by sudden and rapid attack rather than by any steps to secure success by attrition. Such an attack, thanks to the progress of mechanization in armies and to the still more spectacular developments of aviation, will have a combined penetrative and destructive capacity far greater than has ever been possessed by a military force before. The defence, then, is faced with the problem of meeting a powerful attack, probably coming with very little warning and able, at the same time, to strike at the front and at rearward objectives.

2. Nations with vulnerable land frontiers meet the problem by fortification and the modern tendency is to construct these fortifications along the frontier. It is no longer sufficient to use fortification merely as a means of economizing forces and gaining time. The effect of modern weapons is to reduce the battlefield to a heap of ruins. National territory cannot be exposed to this danger. Moreover, the army is no longer supplied in war from a few arsenals; the whole country is mobilized to supply the fighting forces. Hence the loss of any territory means a breach in the military supplies. It is more than ever important therefore to prevent war being waged within the frontier. For this reason frontier fortification to-day is devised to prevent any overrunning of the country. The old closed system of fortress, often placed far behind the frontier, has been replaced by the "chaine" system, which carries the defence right up to the frontier. The links may be of unequal size, but they are welded together by cross-fire. The general principle is a screen of concrete machine-gun emplacements along the frontier, with a defensive system in depth consisting of a series of mutually supporting works. Provision is made for the rapid execution of field defences to fill the gaps between the permanent works, and demolition schemes are prepared to delay any advance and to prevent an irruption by a mechanized force on the outbreak of hostilities.

3. The effect of this fortification of the frontiers may be to introduce static warfare conditions from the very start of a struggle. Even where a campaign begins with mobile fighting, the addition of an obstacle to a defensive position may bring an offensive movement to a definite halt. Position warfare may begin with entrenchments hastily dug by both sides in the course of the open fighting and develop, as time goes on, into what for all practical purposes is siege warfare. Between the two extremes of hasty entrenchment and regular siege processes there will be several stages; varying degrees

of expansion and improvement in defence will meet correspondingly intensified forms of attack. In some cases, such as rear systems, an elaborate defensive system will be laid out deliberately.

4. The modern defence system has to provide cover against heavy bombardment. This usually implies mined dug-outs or concrete blockhouses. The introduction of the tank necessitates the provision of special obstacles and obstructions. Defence against gas has to be considered, not only from the point of view of excluding noxious gases from the works and dug-outs, but with a view to ensuring a fresh air supply and and decontamination of affected localities and structures. All defence works have been affected by the development of the air arm. Their concealment from the observer in the air and camera is a matter of considerable importance and precautions are necessary, in rear as well as in forward areas, to limit the destruction to material and personnel from bursting bombs.

4. Conclusions

1. The war of 1914-18 showed that properly organized trench systems, suitably provided with barbed wire and underground cover, were a most effective means of defence. It emphasized, too, the tactical unsoundness of linear defence.

2. The pre-1914 form of fortress was an aggravated form of linear defence ; reliance was in most cases placed on a single girdle of forts, sited on points of great tactical importance. The fall of any one of these forts at once gave the attacker possession of observation and command over the interior. Further, the juxtaposition of heavy artillery and infantry in the same fort was much to the detriment of both.

A defensive position, to resist an attack supported by modern weapons, must be organized in depth. If the position is required to cover a point of strategic importance, such as a railway junction, a river crossing or a city, the defences must be sited sufficiently far in advance of it as to prevent the enemy from destroying it with his long-range weapons. Also the foremost defences must be far enough in advance of the localities required for artillery observation to ensure that these localities shall not be captured, and the eyes of the defence blinded, by a minor attack by the enemy.

3. Positions for all-round defence, on the principle of the ring fortresses of the past, are no longer practicable. The area to be enclosed would be so vast that an army would be required to defend it. To allow so great a force to be cut off from its communications and from touch with the remaining

field armies, and to be deprived of its mobility, is not to be thought of. Further, the consumption of ammunition in modern battles is so enormous that, unless communications remain open, the defence could not last long.*

Permanent or deliberately prepared defences under modern conditions will take the form of large fortified regions fulfilling one or other of the following functions :—

i. As pivots to support the operations of field armies.
ii. To close to the enemy a line of advance which cannot readily be turned or passed by.
iii. As a barrier along a line of frontier. Such a barrier would not necessarily be continuous, but the gaps between would be such that an invader using them would be subject to great disadvantage.

4. The organization and lay-out of any defence system must conform generally to the principles laid down in Field Service Regulations, Vol. II, 1935, Chapter VII. These principles apply equally to a hastily organized defensive position, occupied when in touch with the enemy, to deliberately prepared defences such as rear positions, switch lines and other field defences prepared before contact is established, and to permanent defences constructed during peace. The guiding idea in every case is to create a network of defended localities, echeloned in depth and affording each other mutual support. Hasty defence is dealt with in the Manual of Field Engineering ; deliberate defence will be treated in the two following chapters of this manual ; and permanent fortification in Chapters IV and V.

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* During the seven months of the defence of VERDUN in 1916 *a daily average* of 100,000 shells of all calibres was fired by the defenders. On days of attack the consumption was more than double the above.

CHAPTER II

DELIBERATE DEFENCE—NATURE AND EXECUTION OF THE WORK

5. Categories and principles of deliberate defence

1. An elaborate defensive system may arise in several ways. It may begin with entrenchments hastily dug in the course of open fighting and gradually elaborated and improved as time goes on into a system extending to a depth of several thousands of yards, strengthened by concrete works and shelters, by deep dug-outs and by wide and formidable obstacles, equipped with all the paraphernalia of position warfare. On the other hand, it may be a position deliberately selected and prepared in advance. Rear positions and switches are examples of this category. Again, it may be called for in completion of peacetime plans, to fill in the gaps between the permanent fortifications of a fortress or to cover the land side of a defended port.

2. The principles of defence, applicable in every case, are those laid down in Field Service Regulations, Vol. II, 1935, Chapter VII. Depth and elasticity are the essential requirements. Every position must be organized in depth. This applies not only to the distribution of the infantry and machine guns, but equally to the artillery and other weapons. It reacts, therefore, on the whole of the defences and governs the location of every work, fire trench, shelter or obstacle. It is depth that gives elasticity to a defensive system, enabling it to bend the attack without being broken. This implies a certain fluidity in the defence and therefore calls for a degree of freedom of movement within the system. This last is met by communications, by the linking-up of the various posts with communication trenches or other covered ways designed to secure freedom of movement to all places within the system and at all times.

3. No matter what the type of defensive system or the method of its creation, the eventual organization to be aimed at will be a *main zone* selected as the most favourable position in which to meet and repel any serious attacks by the enemy and an *outpost zone* to act as a buffer and absorb the first shock. Behind the main system, at some distance in rear, if time and labour permit and there is a possibility of having

to stand very heavy attacks, *rear zones* may be constructed or at all events reconnoitred and planned.

The main zone will be organized for defence in depth. It will consist of strong successive systems of defence, each comprising front, support and reserve trenches or posts, joined together laterally and from front to rear by communication trenches. Diagonal switch lines, supporting points and defended localities, must be constructed to prevent the enemy, should he succeed in temporarily penetrating the defences, from spreading outwards and rolling up the position.

The outpost zone will also be organized for defence in depth. It will be sufficiently garrisoned and strengthened to guard against surprise, to break up the enemy's attacks and compel him to expend large quantities of ammunition and employ strong forces for its capture. As a rule a single system of defence comprising front, support and reserve trenches or posts should suffice. The backbone of the defence in this zone will be machine guns skilfully concealed with wire entanglements and anti-tank obstacles.

The rear zone should consist of at least one complete system of trenches or posts and should be connected to the rear system of the main zone by switches.

4. In the case of a defensive system which is being developed during the stress of active operations, the locations of the main and outpost zones are largely determined by the positions of the forward troops in contact with the enemy when movement ceased. Within the limits thus imposed, the main zone will be selected where the ground is, or can be made, favourable to the defence. The high-water mark of the advance will constitute the front of the outpost zone. Under conditions such as these, the scope and rate of progress in the development of a defensive system is likely to be severely restricted. Time, labour and materials will all probably be insufficient for the tasks involved; direct interference by the enemy must be expected and may well make the maintenance problem of works constructed a very considerable one. Where a position is being selected deliberately and prepared before contact with the enemy has been established, the siting of the main zone will be determined chiefly by features of the ground so as to make the best use of observation, cover and existing obstacles. The time likely to be available will be known and the resources in labour and materials can be organized accordingly. It is not to be expected that there will always be sufficient time to complete the whole system, but there will be a period, greater or less, in which work can be carried out free from interruption from the enemy. Labour battalions and

possibly civilian labour may be used in some cases and in rear areas mechanical plant as well.

Defences to supplement permanent fortifications will have been planned in peace and the method and means for their execution settled in detail. When the work is ordered, on mobilization or during the precautionary period, all that will remain to be done will be to set the plans in motion and supervise their execution.

6. Development of a defensive system from hasty entrenchments

1. Entrenchments thrown up hurriedly or adapted from enemy lines as captured are necessarily of an elementary nature and will rarely be sited to the best advantage. As a rule they will mark the high-water mark of the advance, rather than the best tactical position. One can picture trenches which are either shallow or else much battered by bombardment, extemporized gun emplacements, little wire, no deep dug-outs and no deeply buried signal systems.

2. The first step, when the decision is made to adopt a defensive role and to prepare to meet a strong and sustained hostile offensive, will be the selection of the three zones of defence, the outpost, the main and the rear. The outpost zone will usually coincide generally with the existing front system. The main zone will be selected on the best ground available for fighting behind the outpost zone. The rear zone, which is in fact a second position, may be four to eight miles behind the main zone. The general policy for the strengthening of these zones will be laid down with the relative importance to be given to the various localities and works, and arrangements made for the desired distribution of labour, for the provision of the necessary materials and for the development of road and light railway communications.

3. The strengthening of the existing defences will usually involve :—

i. Improvement and extension of obstacles, both wire and anti-tank ;

ii. Shell-proof accommodation, including machine-gun emplacements, observation posts and battle head-quarters.

iii. Organization in depth of infantry, machine guns, mortars and artillery ;

iv. Interconnection by communication trenches of posts and defended localities and improvement of roads and tracks.

The order of priority for the construction of defences will vary with circumstances. Enemy action, the weather, the amount of labour available and the supply of materials will all have their effect in determining the progress made or the urgency of the work. The first essential, however, will almost invariably be wire and, where attack by armoured fighting vehicles is possible, obstacles against these as well. Highly important, too, is the connection by continuous trenches of the various posts and localities which form the framework of the position. Only by this means can freedom of movement within the system be obtained and the enemy be prevented from pin-pointing the garrison of each post. Steps must be taken early, too, to provide cover for these garrisons, firstly from the weather and secondly from hostile shelling. Protection from the latter will call for mined dug-outs or concrete structures.

4. In the construction of defences a careful planning of work and the suitable distribution of the available labour and material are the chief means of securing good results. Comprehensive plans, covering a considerable period ahead, should be drawn up, and should not be departed from; otherwise waste and delay are inevitable. In order further to ensure continuity of work, officers should be placed permanently in charge of definite sectors of the main zone.

The constant improvement of the road, railway and trench tramway systems for carrying material, ammunition and supplies is of great importance in the construction of positions. A good tramway system is of particular importance where it is intended to undertake concrete work.

7. Deliberate preparation of a position

1. The *responsibility* for the selection and general organization of a defensive position will ordinarily lie with the commander of the formation or formations in whose area the position is located. In special cases a separate organization and commander may be created for the purpose.

2. The *general line* of defence depends on the strategic situation and will be decided by the higher authorities. When this has been done, the commander concerned settles the main tactical features which it is essential to hold. He will do this in the first instance, as a rule, from the map, after which the necessary reconnaissances can be carried out for the organization and siting of the main system.

3. The *main zone* should be organized in depth on the following lines:—

i. The first consideration is the defence of the main tactical features. This is usually best secured by

defending the lesser tactical features which lie in front or on the flanks. The infantry defences will usually consist of front, support and reserve trenches and will be supported by a thorough fire system of other weapons (machine guns, anti-tank guns and artillery) distributed in depth. The infantry trenches must be well forward of the main tactical features which they are designed to defend, so as to give room for the machine-gun defence, and it follows that the machine-gun defence must be considered at least at the same time as the infantry trenches. Again, adequate forward observation for the artillery is essential and often can only be obtained either in, or close behind, the front line. This requirement must be kept in view in selecting the front line. The distances between the front and support trenches may be 150 to 200 yards and between the support and reserve trenches 500 to 800 yards. Although trenches must be separately selected for the defence of each tactical feature, they should usually be joined up to one another so as to form continuous lines and thus constitute a complete defensive system along the whole front and one in which centres of resistance cannot be picked out.

ii. Behind this foremost system of defence in the main zone, which should be regarded as the main system of defence, a further system of trenches or dug-outs will be required for the accommodation of infantry reserves, and these should be organized into tactical localities with trenches connecting them. They may be either on or behind the main tactical features, to which reference has already been made.

4. The *outpost zone* in front of the main zone must be organized and prepared as part of the latter. It should form a buffer zone, organized and held in such a way as to absorb the shock of the attack, to deprive it of its momentum and to break up the enemy's organization as far as possible. It should occupy all ground necessary in order to get immediate information of any hostile movement.

The organization and siting of the outpost zone will be carried out on the same lines as that of the main zone. As, however, it will be only lightly held, it is not necessary that the trench systems should be so highly organized, nor need the various lines be continuous. The line selected as the outpost line of resistance should, however, be as strong as possible, and the whole zone should be sufficiently complete

to prevent those parts which are occupied and dug to full depth from being conspicuous targets, to facilitate communication and command, and to conceal from the enemy where the outpost zone ends and the main zone begins. In this connection particular attention is necessary to the employment of camouflage.

5. The *rear zone* is for use in the last resort. It should be constructed on carefully chosen ground sufficiently far in rear of the main battle position to make it necessary for the enemy to organize a second and distinct operation in order to attack it.

6. *Switch lines* and fire-stepped communication trenches should be provided between the rear line of the outpost system and the main system so as to facilitate the throwing back of defensive flanks, if necessary, from the outpost system or the preparation of counter-attacks from the main system. A similar procedure should be adopted to connect the main system to the rear zone.

7. Every defensive system must be provided with *obstacles.* A continuous line of wire should be erected along the entire front, this being the first work to be done. In addition, every post should be completely wired round and be suitable for all-round defence. Rays of tactical wire must be erected in conjunction with the siting of the machine guns.

Where attack by armoured fighting vehicles is anticipated, the selection of the main zone will have been governed by the existence or otherwise of natural anti-tank obstacles. In any case, where such an attack is possible a reconnaissance of the front of each system will be made to determine the extent to which these cover the front. The gaps will have to be filled by anti-tank mines, artificial obstacles or the provision of anti-tank weapons.

8. *Shell-proof accommodation* will be required for every defensive zone. The positions where it should be provided must be decided as early as possible and should be sited in accordance with the general scheme of defence. Shell-proof and bomb-proof protection is best obtained by deep mined dug-outs or concrete structures. The former have the objection that their depth prevents the garrison getting out quickly ; they should never be used in advance of the support trench of the front-line system.

9. The *priority of work* on the construction of the various parts of the defensive system will depend on the time likely to be available, on the nature of the attack expected and on the labour and material available. The construction of an extensive position requires a great deal of labour and material

and a good output of work depends on skilled supervision and a well-organized distribution of the working parties and the materials. If there is no reason to expect that the position will be subject to attack before its development is well advanced, the order of priority may be decided almost entirely with a view to ensuring the most efficient progress of the work. If, on the other hand, attack is possible before the development is complete, the order must be settled by tactical requirements.

8. Filling the gaps between permanent fortifications

A considerable amount of work will be required either during the course of hostilities, or in immediate anticipation thereof, to link up redoubts, defended posts, etc., and to complete the defensive system inaugurated in peace.

The main requirements will be :—

i. The provision of forward and lateral communication for purposes of control and maintenance.
ii. The establishment of connecting posts and the construction of sections of fire trench, to protect the intervening ground at night or in mist or fog.
iii. The completion of gun positions.
iv. The extension of the subterranean system, *i.e.* subways and deep level accommodation for personnel and stores.
v. The clearing of the foreground, and the carrying out of the arranged scheme of demolitions.
vi. Anti-tank obstacles and inundations.
vii. Works in the back area, including the erection of huts for camps, hospitals, stores depots, etc.
viii. The preparation of aerodromes and landing grounds.
ix. Works on roads, railways and forward tram lines.

All such work will normally have been planned and tabulated beforehand, and the necessary information for the beginning of the work, with priority of execution, will be found in the defence scheme (*see* Sec. **35**). The general organization and method of carrying out the work will follow the lines described in the succeeding sections of this chapter.

NOTE.—In the form of an Appendix (p. 163) is an example of the general instructions issued for the construction of a rear defence zone.

CHAPTER III

DELIBERATE DEFENCE—DESIGNS AND DETAILS OF STRUCTURES

9. General principles

1. Both in number and in design the field defence structures employed in deliberate defence vary enormously according to the time and the resources available for their construction. Where time is very limited, the works will not differ from the field defences of mobile warfare and are described in the Manual of Field Engineering, Vol. I (All Arms). Where time and resources are plentiful, they may approximate to the simpler forms employed in permanent fortification.

2. Generally speaking, the principles of design to be observed are simplicity so as to minimize the use of skilled labour, avoidance of complicated casings and special forms of steelwork, and full use of local materials so as to reduce the transport of materials. Designs should be standardized as much as possible, and minimum thicknesses of roof and walls to give the desired protection should be employed.

3. Concrete and reinforced concrete are generally the best all-purpose materials to be used. Their use is described in the Manual of Field Engineering, Vol. II, 1936, Chapter VII. Timber is not to be recommended, as it is more easily destroyed by artillery fire, but, where supplies are plentiful, its use may be desirable. Standard steel linings are likely to be very useful ; they are simple to erect.

4. To prevent the penetration of poisonous gases, entrances should always be provided with gas curtains (*see* Manual of Field Engineering, Vol. II, 1936, Plate 49), and ventilation should be arranged.

5. The danger that entrances may be blocked by falls of earth or shell fire has always to be borne in mind, and alternative ways or protection against collapses should be provided. Nothing that will hinder troops from getting out of the shelters, etc., quickly can be permitted.

6. The vital importance of concealment must be taken into account at every stage of the work. Before materials are collected or any work done on the site, it must, if there is any chance of enemy air observation, be camouflaged. The

most suitable form of camouflage will usually be that consisting of a horizontal net fixed on wires. During the execution of the work, care must be taken to avoid collecting material or spreading new earth outside the area covered by the camouflage. All newly excavated earth under the camouflage must itself be covered with camouflage material ; otherwise it may be visible on aeroplane photographs.

7. Owing to the great amount of labour required for the construction and maintenance of extensive positions, it will often be necessary with rear positions to be content with marking out the trenches and with constructing the framework only, *i.e.* the machine gun and anti-tank gun positions, dug-outs, observation and command posts, obstacles, ammunition stores and the drainage system. The actual digging of the fire and communication trenches must often be wholly or partially deferred.

8. In laying out the position, the wet season must be taken into account, *e.g.* approach trenches in valleys should be taken along the side and not down the bottom ; the draining system should be elaborated in good time during the dry season. Success or failure to ensure good drainage may be the deciding factor whether the position can or cannot be held in wet weather.

10. Shell-proof construction

1. Every effort must be used to provide adequate shell-proof accommodation. This cannot be regarded as less than protection from shelling by 6-in. guns. It is best obtained by deep-mined dug-outs or by concrete construction. The former, as already stated, have the objection that their depth prevents the garrison getting out rapidly ; ventilation, lighting and drainage are often very difficult problems and the nature of the strata may prevent a deep dug-out from being made in the best tactical situation. The mined dug-outs have, however, the following advantages over concrete ones :—

i. Their construction involves less labour in proportion to the accommodation given and affords more immediate results.

ii. They give complete protection, both from actual penetration and from serious concussion effects.

iii. Their exact position can, as a rule, be better concealed, although the spoil removed from them may indicate their existence in a particular locality.

2. In building shell-proofs in the front lines of positions the main point to be borne in mind is that the occupants must be able to reach their fire positions quickly. Shelters for small

numbers and which are not deep are therefore implied. In the rearward areas and off communication trenches the shelters may have a greater capacity (up to a platoon, say) and may be made deep.

3. In all dug-outs the problem of ensuring that the troops can get out quickly is of the utmost importance, and the larger the shelter the more necessary is it that it should have convenient, concealed and well-protected exits. Special measures will often be needed to guard against blocking by earth falls or destruction and absolutely reliable alarm systems must be arranged. The best shell-proof dug-outs are not merely worthless, but are dangerous if the men in them are likely to be cut off and prevented by ill-arranged or non-shell-proof exits from reaching the firestep in time to meet an attack. For this reason it is undesirable to protect exits against the weather by cover which is only splinter proof, for this will increase the danger of having the trench blocked. For the same reason swing doors should not be used in dug-outs owing to their liability to being blocked by falls of earth and because their debris after a bombardment may impede traffic.

4. The construction of tunnelled dug-outs and concrete shell-proofs is described in the Manual of Field Engineering, Vol. II, 1936, Chapters V and VII. The examples given are all applicable to deliberate defence and will differ, as a rule, only in the fact that the work can to a greater extent be planned in advance.

11. Machine gun emplacements

1. Several types of machine gun emplacements are described in the Manual of Field Engineering, Vol. II, 1936, Chapters III and VII. It will be seen that the roof of a reinforced concrete emplacement (*see* Manual of Field Engineering, Vol. II, 1936, Plate 24), if built in the open, will be some 5 ft. above the ground. Concealment in such situations may be difficult and will certainly require special attention. The Champagne type emplacement (*see* Manual of Field Engineering, Vol. II, 1936, Plate 23) is invisible to ground observation and easily camouflaged from the air. It can, of course only be used in localities where the water level admits of the construction of dug-outs.

2. Where work on the site has to be reduced to a minimum, concrete emplacements can be built with pre-cast blocks.

12. Command and observation posts

1. Headquarters must be kept as small as possible, both to keep down the work of their construction and to facilitate

concealment. Examples of tunnelled and concrete headquarters are shown in Plates **1** to **4**. On high ground it may sometimes be possible to provide shelter for subordinate personnel below the battle headquarters ; where this cannot be done, a second shelter must be made close at hand.

2. Observation posts must not be recognizable as such by the enemy and yet must afford sufficient view. These two requirements will often conflict, particularly in flat country where height is necessary for observation. Skilful use must be made of the ground and of camouflage. With a low command (one foot to one foot four inches) the portion of the observation post above the level of the loopholes cannot be made shell-proof without armour plating, but this disadvantage will have to be accepted.

Most infantry observation posts should be in the main zone and have frontal observation. Some may be arranged for flank observation or on commanding positions in rear. Facilities for direct observation and for observation through periscopes should be provided. For direct observation a slit about $\frac{3}{4}$ in. wide and about 5 in. long should be sufficient. The periscope would normally be used through a hole in the roof.

Artillery observation posts must be particularly carefully hidden and of shell-proof construction. If they are in the infantry line or close to it, they are very liable to be destroyed before they are of any value. The most important observation posts should therefore be so far back as not to be exposed to fire directed on the trenches. Reserve and emergency observation posts should be provided.

3. Examples of observation posts are given in Plates **5** to **8**.

4. Arrangements for communication between the trenches and the command posts and between the latter require careful consideration. Special dug-outs for wireless sets will be necessary at the command posts of battalions and higher formations.

13. Artillery emplacements

1. Cover for artillery is constructed similarly to other shell-proofs. As a rule it should be undertaken in the following order :—

i. Cover for the gun detachment.
ii. Cover for the ammunition.
iii. Cover for the gun.

2. In certain cases it may be found that security against hostile artillery is mainly to be found in mobility (*i.e.* changes of position). A number of less protected alternative emplacements will therefore be preferable to a few strong ones.

3. Details of gun emplacements are given in the Manual of Field Engineering, Vol. II, 1936, Chapter IV.

14. Ammunition stores

1. Particular attention must be paid to the proper storage of all kinds of ammunition. Small arms ammunition, grenades, etc., for which wooden boxes and tin cases protected against damp are provided, may be stored in recesses under the parapets of trenches.

2. Artillery and trench mortar ammunition should be stored in deep mined dug-outs, if possible, with cartridges and shells in separate chambers. Too much ammunition should not be kept in one place ; it is better divided among a number of small ammunition dug-outs.

CHAPTER IV

PERMANENT FORTIFICATION—NATURE AND EXECUTION OF THE WORK

15. General principles

1. Permanent defences must provide for the use of all types of modern weapons, including tanks and aircraft, and for defence against all such of these as the enemy is capable of bringing to the attack. In designing defences in peace, it is important to bear in mind the probable changes in weapons which the future, as far as can be foreseen, is likely to bring forth. It must be remembered that armies and air forces can be equipped with new weapons far more quickly than fortifications can be built to resist them, and that it is highly probable that works designed to resist the weapons of to-day will be of little value against the weapons of thirty years hence. In fact, the actual construction of permanent defences has the effect of leaving the initiative with the expected attacker, who, if he is a first-class military power, may be confidently expected sooner or later to produce a weapon capable of destroying them. Permanent defences must, therefore, be kept up to date. It is, however, difficult to remodel existing works, and an adaptation to changed conditions can generally be secured only by their entire demolition and the construction of new ones on a new lay-out. Such a process is lengthy and, if war supervenes before it is finished (as at Warsaw in 1914), no defence at all may be available.

2. It is of the first importance that the positions which it is proposed to fortify in peace should be selected in accordance with a definite scheme of national policy, in which the proposed action of the field armies is clearly defined. It must be remembered that under modern conditions defensive positions cannot fulfil their functions except in close connection with the operations of the field armies outside them, and will generally have to be abandoned if those field armies cannot prevent the enemy from turning their flanks and surrounding them.

3. National policy, however, is liable to change in accordance with the progressive development of weapons and means of communication, and also with changes in the nation's political relations with other states. Even if the fortifications have been conceived in the first place on sound strategical principles, changes of the above nature may result, a generation later, in their being in the wrong place and unable to

play the part contemplated for them in the strategic conditions which did not arise.

4. The above conclusions lead to the necessity for considering seriously whether the provision of permanent fortifications in peace is desirable at all. If a carefully prepared and up-to-date scheme exists, if adequate labour and the necessary materials are available, and if reasonable time for preparation is given, it will be possible, even after the outbreak of war, to prepare a defensive position which, by reason of its accordance with the tactical and strategic conditions of the time and place, would be of far greater value than permanent fortifications constructed twenty or thirty years earlier to meet quite different conditions.

5. From the purely tactical and material point of view, therefore, it would appear that, owing to the rapid progress in military invention which the scientific and industrial conditions of this century bring about, it may be unwise to rely on permanent works of a tactical nature for the defence of strategically important regions against the weapons of the future. Their defence could best be secured by sound strategic dispositions of field armies adequately equipped with modern weapons. These dispositions can, however, be facilitated and strengthened by the provision in advance of certain works necessary for the organic working of a defensive position, leaving the provision of *tactical* defensive works, *i.e.* the fighting positions of infantry, machine guns and artillery and the construction of obstacles, to be provided nearer the time they are likely to be required, or even, if necessary, after the outbreak of war, thus avoiding the danger of premature obsolescence.

6. It must, however, be remembered that a plan of campaign may be forced to envisage defensive operations on a part of the theatre of war so soon after the opening of hostilities that time will not be available for the preparation of defences even of field type. In such cases also the preparation of defences during the period of tension previous to the outbreak of war may be considered inadvisable. It may be necessary to gain time for the armies to mobilize and assemble by providing near the frontier fortified regions which it would be unwise to leave unprepared for defence until the outbreak of war. Also there are other considerations besides military ones which may affect the problem. Such, for example, are political considerations, in connection perhaps with possible allies ; psychological considerations, such as the effect on the populace of the surrender to an invader of large tracts of territory ; or industrial considerations, which may make it necessary at all costs to prevent the irruption of the enemy

into important industrial areas or coalfields. In cases of such nature, which are common in Continental countries, it will generally be found necessary to undertake the complete organization and execution of the essential defensive works in peace.

7. It will be realized that a nation with a long and vulnerable land frontier, having the will and ability to evolve and construct a defence line on modern principles and to keep it up to date as developments occur in armament and methods of fighting, will find itself in a favourable position as regards man-power and morale on the outbreak of war, whether having to fight offensively or defensively. In either circumstance such a nation will be able to turn into the field every man who is not required for such essential services as railways, ordnance factories, food supply, etc. Nor will its nationals be liable to suffer from panic or apprehension of a disastrous invasion or incursion on the part of the enemy. Loss of the initiative, and a great expenditure of man-power and material on work services, will be the inevitable result of the neglect of such peace-time construction, coming at a time when every endeavour is essential for the active prosecution and successful outcome of field operations.

8. In a similar way it may be advisable to build certain permanent works in peace-time on the land fronts of important towns or naval bases in colonial possessions. The inception of such work may be inadvisable shortly before war, or during a period of international tension ; and after the outbreak of war it may be very difficult to provide the men without seriously depleting the numbers available for active defence, nor may time be available to carry out the heavy type of construction necessary in present conditions of war.

16. The modern fortified region

1. The conditions of the deliberate defence considered in Chapters II and III have implied a greater or lesser provision of cover by entrenchment and by the use of materials to hand. There has been, in other words, a considerable measure of extemporization. In permanent fortification, on the other hand, time, labour and material permit the fullest use of reinforced concrete and other materials, and measures as required for the construction of shell-proof cover. Tunnels can be provided for communication and every practical step can be taken to conserve man-power and to enable the defender to make the fullest possible use of his weapons.

2. The actual lay-out of a defended area will depend on the force available to man the defences, on the armament to be provided and on the nature of the terrain, which may be

naturally strong in itself and easily adaptable to defence, or the reverse. But in every case the problem to be solved is to occupy the ground in such a way as to make the fullest possible use of automatic weapons, based on a system of mutually supporting works, assisted by the delaying power of formidable obstacles, and the covering fire of a powerful artillery on all the attacker's approaches. The defended area may vary in depth, within the limits of three to ten miles, and it will consist of a forward position composed of a screen of concrete machine gun posts or pill-boxes, covered by wire entanglements and anti-tank obstacles ; an intermediate zone of small detached works or defended posts sited on suitable tactical features, so as to control the terrain between them ; and a main position, consisting of a non-continuous chain of redoubts or detached works, prepared for all-round defence and capable of putting up an intense resistance.

3. The artillery of the defence will consist of guns, howitzers and mortars of all natures and calibres up to the highest. Except for the mortars, semi-automatic and anti-tank guns, included in the armament of the redoubts, all the artillery will be in carefully chosen battery position outside the works, and so disposed as to cover with their fire the whole of the ground over which the enemy must advance to the attack of each of the three positions. Some of the heavier calibre weapons will be intended for counter-battery work.

4. There will be aerodromes and landing grounds, generally at a distance in rear, for the service of the air force co-operating in the defence, and a complete system of anti-aircraft guns and lights, with their necessary signal communications, for defence against the enemy's aircraft.

5. Besides the works necessary for fighting purposes, the following are the principal other features of a modern fortified region :—

i. A complete system of communications between the various works and artillery positions, and leading up to them from the rear. These will, to the utmost extent practicable, be in the form of underground tunnels or subways, supplemented by trenches excavated after the outbreak of war.

ii. Underground shell-proof headquarters for all formations and units.

iii. A complete system of signal communications connecting all these headquarters.

iv. Observation posts as required for artillery, infantry and intelligence purposes.

v. Underground shell-proof cover for reserve troops in suitable positions.

6. The design of all permanent defence works has been largely influenced by the development of air warfare, both as regards invisibility from the air and protection against bombing. The introduction of tanks necessitates the use of special obstacles and obstructions, since the usual barbed wire entanglement does not constitute an effective barrier. Defence against gas has to be considered from the point of view not only of excluding noxious gases from the works and dug-outs, but also of the supply of fresh air and of the decontamination of affected localities and structures.

7. The following are the principal characteristics of a fully developed system of permanent defence works designed to resist attack by a first-class military power :—

i. Fire will be almost entirely flanking or indirect.

ii. There will be no large guns inside a defence work, but there may be small guns mounted in cupolas or firing through embrasures.

iii. Loopholes and embrasures will be located so that adjacent works will be flanked and supported by mutual fire.

iv. All communications within a work of defence will be by tunnels or shell-proof galleries.

v. The outlines and extent of a work will be invisible and indefinable by the enemy.

vi. All wire entanglements and infantry obstacles will be guarded by anti-tank obstructions or mines.

vii. Where possible, mined accommodation will be provided in two or three levels, the dug-outs or barracks for resting troops being at the lowest level.

viii. Subways or tunnels will be extended forward so as to provide sally-ports, and for counter-mining.

ix. Power will be installed or brought by cable from a central power station for working lifts, for providing light and for ventilation and fresh air supply.

x. Searchlights will be provided for lighting the foreground and for anti-aircraft defence.

xi. A pressure water supply system will be installed, by which reserve tanks in all works will be kept filled.

xii. A foul drainage system will be provided to get rid of waste water and sewage.

8. Further, to complete the picture of a fortified region, a comprehensive and well-considered scheme is required for utilizing the country in rear of the defence position. Troops must be fed, casualties evacuated and replaced, and a continual flow of ammunition, equipment and engineer stores maintained for the defence system. Thus it is essential, in the first instance, to provide for a complete system of roads

and railways, leading up from reinforcement camps, base depots and supply parks, as well as for adequate lateral communications. In addition, sites must be selected and provision made for the accommodation of troops in reserve, hospital and casualty clearing stations, and for stores depots of all kinds—aerodromes with landing grounds, workshops and petrol stations will be required for co-operating air units. The defence of the back area against air attack and against raids by mobile armoured forces must also be considered.

17. Infantry positions

1. The concrete works of the forward position will normally consist of an emplacement for two machine guns, surmounted by a cupola for an observer and having one or more light machine guns for close defence. A shelter will be provided under the emplacement for the garrison, which will consist of about twelve men.

2. The works of the intermediate zone will consist essentially of a number of tunnels or galleries, below the surface, connected with small concrete chambers on the surface, having openings or embrasures, through which the defender's weapons will fire. The weapons will be principally machine guns, which will employ flanking and reverse fire with a minimum of direct fire, so as to expose as few vulnerable elements as possible to direct fire from the enemy. The intervals between these works, and their immediate fronts, for close defence, will be protected by infantry in fire trenches, connected to the works by galleries or communication trenches. Shell-proof accommodation will be provided for the manning details and local reserves, ammunition and stores.

3. The detached works of the main position will vary in size according to the tactical importance of the position which they occupy, and according to the nature and strength of fire power which they are to develop. As a rule, the larger works or redoubts will occupy the commanding portions of the position, and they will be equipped with a large number of machine guns, supplemented by mortars, anti-tank guns, anti-aircraft equipments and searchlights. In some cases semi-automatic artillery will be installed, either in cupolas or in casemates. The smaller works will not be so heavily armed and will be sited on the minor or less important features, so as to cover ground not under fire or observation from the redoubts. All the works in the main position will be mutually supporting and will employ mainly flanking and reverse fire. They will consequently offer very few vulnerable targets to direct fire from the enemy. The actual front of the redoubts and works will present a definitely shell-proof

thickness of earth, or mass of concrete, against the heaviest bombardment, while all communications to machine-gun emplacements, gun cupolas, observation posts, etc., will be by means of tunnels or well-protected galleries. There should be very little to be seen of this type of permanent work, either by ground or air observation, no prominent features to act as aiming marks and very few vulnerable points to hit. It is essential that the general lay-out of the works should be such as to facilitate the division of the defensive position into corps, division and infantry brigade sectors, every group of works, together with the trench defences which will be prepared when required, forming a tactical unit, *i.e.* a platoon or a company.

4. The various redoubts and works in the main position will be connected in war by well-reveted communication trenches, leading to sections of fire trenches, small defended posts or assembly trenches, which will be occupied according to the needs of the situation during operations. Similar communication trenches, connected by lengths of tunnel to the interior of the permanent works, will lead to the front and rear, for the passage of troops, stores and ammunition. All these communication trenches should be laid out to suit the division of the position into formation, and unit sectors as referred to above. If possible, each infantry brigade sector should have one communication trench for forward traffic and one for return traffic. The dressing stations should be connected with the latter. Thus the battle position will develop in time into an organized trench area for defence and inter-communication, based on the chain of permanent works, constructed and equipped in peace.

18. Artillery positions

1. The artillery dispositions should be fully worked out in peace, and the site of every battery and of each gun fixed. The disposition should be such as to admit of the possibility of concentrating the fire of the whole or nearly the whole of the defence artillery against an attack directed against any portion of the defensive front. Thus there will be, taking the position as a whole, considerably more battery positions than batteries, so as to admit of the latter being used in any sector of the defence, as may be required. The position of each gun will be accurately resected and marked on the artillery fighting maps, and a range chart prepared for each command post. These positions may, with advantage, be marked on the ground to facilitate identification. Range marks should also be constructed where necessary and their positions entered on the maps.

2. *Peace preparations.*—The following permanent works can be prepared in peace. They must be well concealed both from air and ground observation :—

i. An adequate system of observation posts.
ii. Command posts for every battery, and, where necessary, for sections of a battery.
iii. Headquarters of artillery brigades.
iv. A complete system of telephone communications (buried cables) for the artillery command, including connections to artillery observation posts and to infantry headquarters of sectors.
v. Chambers for wireless installations.
vi. Sound-ranging installations.
vii. Shell-proof cover for personnel of batteries.
viii. Shelters for ammunition.

3. *Gun emplacements.*—As regards to the emplacements for guns, it will be advantageous to construct in advance concrete platforms or pits for the heavy artillery, but it will not be worth while to do so for the field or medium artillery. It is probable that the latter will be either tractor-drawn or mounted on tracks, so the best provision to make is to improve the approaches to alternative battery positions and provide a hard surface in and about the actual gun sites. In addition to this, an ample store of camouflage materials and of material for the construction of splinter-proof cover should be available for use on the outbreak of war.

4. Railway mountings will be very largely used for the heavy types of gun and howitzers. It may not be desirable to complete the spurs leading into the gun positions in peace, but the survey of all such work should be undertaken and recorded. A good deal of the formation work can, however, be carried out in advance, especially in wooded country where camouflage and concealment are easy. All concrete gun platforms or pits constructed in peace should be entirely concealed. This can be done by covering them completely with at least two feet of soil. Their situation should be ascertainable only by measurement from fixed points in the vicinity. Judicious tree planting, in peace, in the heavy gun areas will form an invaluable screen from air observation when the batteries become active in war.

19. Aerodromes and aircraft landing places

Landing facilities and accommodation for air formations will be required at the earliest possible moment after the outbreak of war, so it is important to select sites and carry out essential work in peace.

Since aerodromes can be sited at a considerable distance in rear of the battle zone, a large choice of positions is usually available. The main considerations are suitable terrain for a landing ground, road and rail communication and an adequate water supply. The first consideration is the landing ground, and, provided that a reasonably level area of sufficient size is available, there should be little difficulty in getting this freed of obstacles, such as furrows, ditches or banks, levelled where necessary and drained, without attracting undue attention or giving its position away. Other necessary works include the provision of hangars, workshops, petrol installations and accommodation for personnel. Workshops, petrol installations and a nucleus of the accommodation required should be arranged for in peace (*see* Military Engineering, Vol. VII, 1934, Chapter XXXVI).

20. Tanks

1. A considerable amount of work should be done in advance to facilitate the movement and action of the defenders' tanks in active defence and counter-attack. Under this heading will come :—

i. Improvements of communications across country.
ii. Bridging requirements, including stability of existing bridges and new construction.
iii. Arrangements for entraining and detraining tanks.

Measures should also be taken, as work proceeds in the fortified region, to safeguard communications and other installations likely to be damaged by the movement of tracked vehicles, particularly railways and tramways.

2. Sites will be selected beforehand and earmarked for tank accommodation. Headquarters for formations and workshops, etc., can be located at some distance in rear, where they would have good road and rail access, with billeting or camp facilities. But, as tank actions against enemy armoured forces will often arise quickly and unexpectedly, forward positions must also be chosen. These should be well concealed from air and ground observation and afford several and ample exits.

3. The advance of enemy armoured fighting vehicles must be impeded in every possible way, so as to assist the anti-tank armament of the defence. Among the methods available are road blocks, craters, inundations and escarps, as well as the employment of special anti-tank obstacles and mines. Reference is made to these in later sections.

21. Anti-aircraft defence

1. It is necessary to make provision for anti-aircraft defence, not only in the battle zone itself, but also in the back area of the fortified region and along the lines of communication.

2. In the former the anti-aircraft defence will be chiefly of a local character, directed against enemy observation aircraft and low-flying attacks. Against these it will be necessary to install small calibre light machine guns on anti-aircraft mountings in some of the concrete posts and small permanent works, and anti-aircraft guns and equipment in the redoubts and larger works in the main positions. Searchlights may be provided to assist the latter in attacking night bombers, or to break up formations passing over the lines at night for operations in the back area.

3. As regards the defence of the lines of communication and back areas, a completely organized system of anti-aircraft defence is essential to protect the aerodromes, stores depots, railway centres and cantonments. This may necessitate the provision of bomb-proof air defence headquarters and operations rooms of searchlight and sound-locator installations and of complete telephone communications (buried cable).

4. The local defence of aerodromes and of important depots and installations against raids by parties landed from troop-carrying aircraft must not be overlooked. The provision of a strong barbed-wire fence, flanked by machine gun fire from concrete emplacements, will, as a rule, suffice.

22. Anti-gas defence

1. Gas, as a weapon, proved its effectiveness in the Great War, and defensive measures must be taken to meet the possibility of its employment by the energy in future hostilities.

2. Particulars of the characteristics of the weapons and gases, and of protective measures against gas attack, are given in the manual, Defence against Gas.

3. *Influence on siting of works.*—For works deliberately constructed in peace the following measures for gas protection will be incorporated in the design :—

i. The building must be truly gas-tight, *i.e.* all openings of every kind, whether doors, windows, hatches or ventilators, will be provided with gas-tight doors, shutters or scuttles.

ii. A supply of pure air must be available either by pumping under pressure through a degassing plant, or by exhausting the internal air, and arranging that the only inlet is through a filter.

iii. An entrance lobby will be provided with double gas curtains and an air-space, such as are described in the Manual of Field Engineering, Vol. I.

iv. As far as is practicable, the materials used, *e.g.* paint, rendering, etc., will be such as do not readily absorb or retain blister gas and similar substances and can be easily and efficiently decontaminated.

v. A water supply will be provided with suitable fittings for a hose or sprayer in every room and in passages.

vi. A positive pressure of pure air within a building or dug-out is the best possible protection against the ingress of gas, and such provision should be a guiding principle in all designs.

vii. A shifting lobby and storage for clean clothing are required at the entrance to all protected shelters and buildings, so that the wearing of contaminated clothing may not render the air inside dangerous.

A typical design for a deep dug-out, showing fresh air supply and degassing arrangements, is given on Plate **15**.

4. Protective anti-gas measures and precautions against all forms of gas attack for civilian inhabitants or population of any defences, where evacuations is impossible, is the responsibility of the commander concerned ; the execution of such protective measures is part of the duty of the " Air Raids Precaution " organization of the locality.

The specific engineer work, including technical and administrative advice, required in this connection which may devolve on the engineer personnel of the garrison to supervise, and in some cases to execute, may comprise the following :—

i. Provision of gas-proof dug-outs or shelters as far as practicable. These will be allotted to specific factories, streets, etc., as far as accommodation permits.

ii. Strengthening existing buildings and cellars.

iii. Sealing existing buildings against gas.

iv. Decontamination arrangements.

v. Organization of an air raid alarm system with a special signal for gas (*see also* Secs. **98**, **3**, and **117**, **3**).

23. Shell-proof headquarters

Shell-proof headquarters will be provided for all formations, including artillery commands. They will contain ac-

commodation for the commander and his staff, a signal office and an observation chamber. The best form of construction is a mined dug-out at such a depth as to be definitely shell-proof. It should have at least two entrances, which will be reached by tunnels leading back some distance to the rear, or connected with the main tunnel system if one exists. Where direct observation is required a shell-proof observation chamber will be constructed at ground level, or, alternatively, observation will be by means of a periscope from below. The camouflage and concealment of such headquarters from air observation is of paramount importance ; hence it is advisable to carry out their construction in peace, so that the ground may show no signs of recent disturbance. The only means of reaching headquarters should be by underground routes, and no paths or overground access of any kind should be allowed.

24. Shell-proof cover for troops

These must be considered under two categories :—

i. Combat dug-outs or shelters.
ii. Barracks.

The essential difference between the two is that in the case of combat dug-outs it is essential that the occupants shall be close up to their fighting posts and shall be able to reach and man the latter with a minimum of delay, while barracks are intended for troops to rest and sleep in. Combat dug-outs must therefore consist of concrete structures at or near the surface, or at the first level below-ground, while barracks may be either at the second or even third level of the mined system. It is so essential that troops shall rest under conditions as free from vibration and disturbance as possible that the normal arrangement for the occupation of a mined system will be to locate command posts, stores, offices and magazines in the second level dug-outs, immediately below the combat dug-outs, etc., while all barrack accommodation is provided in the third level.

25. Signal communications

The general lay-out of the signal system is governed primarily by the requirements of the artillery of the defence, and communications for general purposes of command and administration are incorporated in this lay-out.

The system consists of protected signal centres joined to one another by deep buried cable routes, those running from rear to front being known as main arteries and those at right angles to them being known as laterals. Observation posts and signal offices of batteries, units and formation headquarters are joined by deep buried cables to the nearest signal

centre. Alternate means are provided for use when the cables are cut ; these means are wireless and visual communication and message carrying by despatch rider or orderly. Special measures such as carrier pigeons, messenger dogs or rockets might be introduced in certain circumstances.

The communications to be provided and the siting of signal centres, signal office, main arteries and laterals are described in Signal Training, Volume I. The construction of the buried cable routes and test points along them is described in Signal Training, Volume IV.

The construction of protected accommodation for signal offices, signal centres and test points must be planned in close consultation with the signal authorities concerned.

26. Observation and intelligence posts

Observation posts are required for the artillery, and look-out posts for the infantry, as well as intelligence look-out posts in each defence sector, connected by telephone to brigade and divisional headquarters. All the above must be sited to command a good view of the country to their front, which entails their being constructed on tactical features overlooking the enemy. Hence it is essential to construct these posts entirely underground with a small well-concealed aperture for observation, or, if a built-up structure is necessary, it should be kept as low as possible and made to harmonize in every way with its surroundings.

Local observation within permanent works, or where mined accommodation exists, can be provided by the construction of a small shaft through which a periscope can be raised, so as to command a view of the immediate neighbourhood.

27. Tunnel communications

It is highly desirable to have as complete an organization as possible of underground passages throughout a land defence system. Not only should all the communications within a work of defence be by means of tunnels or shell-proof galleries, but a similar means of communication should exist between adjacent works and for access to look-out posts, command posts and exits (sally-ports) for counter-attack. Tunnels should also connect the rear of the position with the various defence sectors, thus providing a safe approach for the passage of troops and the conveyance of stores and ammunition, as well as for evacuating the wounded, carrying out reliefs, etc. Such a system will not only minimize the effects of shell fire and bombing, but will also provide a large measure of security against the danger of gas attack, since it is possible to exclude noxious gases by means of gas-tight doors and

curtains and to provide for a constant supply of pure air throughout the subterranean workings. Although it is possible that for financial reasons it may be not feasible to install such a complete system of underground communication throughout a large defence area, as much work as possible should be done on these lines in peace, based on a carefully prepared plan, which can be extended or completed after the outbreak of war. Subways within the works themselves and leading to important headquarters and look-out posts should be regarded as an indispensable peace provision, for only thus can communication and control be assured during a battle.

The following essential services can only be effectively and securely carried out during operations by means of a tunnel system :—

i. Signal communications.
ii. Liaison between commanders and subordinates.
iii. The movement of reserves.
iv. The conveyance and supply of ammunition and stores.
v. The installation of observation posts, by means of periscopes from any point desired.
vi. Protection against gas.
vii. The provision of sally-ports for counter-attack or offensive gas measures.
viii. Laying and renewing anti-tank minefields and preparing wire obstacles.
ix. The start of mine warfare in the latter stages.

28. Road and rail communications

1. A complete arterial system of road and rail communication is an essential provision in the fortified zone. Generally speaking, the bulk of the traffic will be carried by rail until the area of long-range artillery is reached, whence distribution will be by means of roads or tramways.

The deliberate work to be undertaken will include the following items :—

i. *Railways.*—
  (*a*) Improvements to existing tracks, including doubling the track where necessary, and the provision of additional sidings.
  (*b*) New construction, including spurs leading to heavy gun positions, depot and aerodromes.
  (*c*) Construction of groups of sidings within main stores depots.
  (*d*) Improvements and additions to existing stations.
  (*e*) Construction of railheads.

ii. *Roads.*—

(*a*) Improvements to existing roads, including the widening and strengthening of bridges.

(*b*) New roads for forward traffic, and lateral communications.

(*c*) New approach roads to railheads or improvements to those existing.

(*d*) By-pass roads to refilling points, water points, dumps, etc.

(*e*) Switch roads to avoid cross roads or villages liable to be shelled.

(*f*) Entrances and exits to depots, casualty clearing stations, railhead rest camps, etc.

(*g*) Provision of maintenance dumps and of material for road repairs.

2. The communication system constructed in advance may include tramways in the forward area for the supply of ammunition to batteries, or of engineer material, food, etc., to defence works and infantry positions. If not actually laid, the provision and storage of materials for such tramways is desirable.

Full information concerning rail and road construction and repairs is contained in Military Engineering, Vols. V and VIII.

29. Accommodation for troops and hospitals

Schemes will be prepared in advance for making use of the facilities in villages, farms and houses in the back area for the housing of reserve troops and others not in contact with the enemy, and also for casualty clearing stations and hospitals. This will include the conversion of big buildings such as schools and churches for hospital use, and the addition of ancillary buildings such as bath-houses, latrines and cookhouses for the use of troops in billeting areas. Where sufficient billeting accommodation is not available, hutments will be required for troops and hospitals. If these are not erected before hostilities, their sites should be marked on maps and the areas selected kept clear of buildings and other obstructions. It is desirable, however, that the ancillary buildings mentioned above should be constructed in peace, so that they may be available on emergency as the nucleus for temporary camps or bivouacs.

Scales of accommodation, with lay-outs and suitable designs for hutments, are given in Military Engineering, Vol. VII.

30. Accommodation for stores

1. The fortified area has taken the place of the old self-contained system of the entrenched camp or girdle of forts and is therefore dependent on a continual flow of warlike stores of all sorts to keep its magazine full, its engineer parks supplied and its troops fed and equipped during the period of hostilities.

The chain of supply is by means of :—

i. Base depots to
ii. railhead and when necessary, to advanced depots, and thence to
iii. magazines and expense stores within the defence works and battery positions.

2. *Base depots*.—These consist of ordnance store depots, supply depots, engineer store depots, M.T. depots, and ammunition dumps, supplied from overseas or from manufacturing centres. Suitable accommodation will often be available in big works or factories which can be taken over on the outbreak of war and expanded for military requirements. It is not a feasible proposition to provide bomb-proof cover for these big establishments, but reinforced concrete walls should be built to act as traverses, so as to limit the effects of bomb explosion or fire. Mined dug-outs should be constructed for the storage of especially valuable stores, and for the safety of the personnel during air bombardment.

3. *Advanced depots*.—Each defence sector should have accommodation for the storage of its reserve supplies of ammunition, engineer materials, petrol, etc. All such will always be within easy bombing distance and often within the reach of long-range artillery from the enemy lines. In view, however, of the expense and difficulty of devising extensive protection against the destructive effect of heavy bombs and shells, it will, in most cases, be sufficient to conceal the position of such depots by siting them in woods, etc., and to construct them in bays divided by thick walls to act as traverses. Shell-proof storage should be provided, either underground or in reinforced concrete structures, for fuzed shell, small arms ammunition and high explosives required for anti-tank minefields and demolition purposes.

4. *Magazines and expense stores, within defence works*.—These are an integral part of the underground system, and ample accommodation should be provided for stores of food, water, ammunition, spare equipment and medical stores. They will, as a rule, be constructed on the second level below ground, so that the conveyance and movement of stores

will not block the site and galleries in the first level, which must be kept clear for the fighting troops. Engineer stores such as barbed wire, sand bags, pickets, etc., will be normally stored on the surface, well camouflaged and concealed from view.

31. Mobile field parks

These are special engineer establishments located in rear of the main defence position, and are intended to provide the means of superimposing defences in threatened areas on previously prepared frameworks. These parks contain all the tools and materials for the rapid construction of light fortifications, *e.g.* trench-excavators, concrete mixers, light railway plant, cement, baulk timber, steel girders, etc. They are intended for extreme mobility and are served by road and railway, whence they can be despatched to any required destination in the fortified region. Their functions are to construct or repair concrete shelters, tunnel communications, gun and machine gun emplacements, observation posts, etc., as well as to construct and maintain roads, bridges and light railways. They will also undertake any large job of trench excavation either for communications or as a route for buried cables.

32. Obstacles

1. The general principles for the siting and use of obstacles are described in the Manual of Field Engineering, Vol. I, and these apply equally to permanent fortification. Rapidity of execution, however, which is a primary consideration in field fortification, is a secondary one in permanent defence. On the other hand, the obstacles themselves require to be of a more endurable nature for permanent work, since they have usually to be constructed for some time before they are actually used.

Thus steel pickets painted with anti-rust composition and set in concrete blocks should be used for all types of barbed wire entanglements and the wire itself should be of heavy gauge and well galvanized.

A barbed wire entanglement, however strongly constructed, is more or less easily destroyed by tanks, so an obstacle of this nature must always be protected by special anti-tank obstacles or an anti-tank minefield. The best forms of obstacles against tracked armoured fighting vehicles are deep ditches, filled with water if possible, escarps and counterscarps, special obstructions in the form of concrete and steel blocks, and contact mines. Of these, ditches are mainly useful for the immediate defence of a self-contained work or redoubt. The sides must be as vertical as possible

and quite five feet deep, while the width should be such as to prevent its being straddled by a tank. An escarp or counterscarp can be formed by cutting into the natural face of a steep slope, or can be constructed by means of a concrete revetment. If five feet high, these are definitely impossible to tanks, while the counterscarps have the advantage of being invisible from the front and are practically immune from destruction by shell fire.

2. All roads leading into the defended area from the enemy country must be got ready beforehand for cratering, since a hostile incursion or raid by armoured fighting vehicles may be expected at a very early stage of hostilities. For this purpose galleries should be driven under the centre of roads and a chamber prepared for the charge. The best place for cratering a road is at some point where deviation is difficult, *e.g.* where a road crosses a marsh. Schemes for blowing up bridges on the line of approach should also be held in readiness. Depots of explosives should be established within easy reach of the proposed demolitions.

33. Inundations

1. Inundations may be successfully employed as a defensive measure where the nature of the country permits, and form a very effective obstacle against all arms, including tanks.

2. Inundations are only suitable obstacles where passive defence is intended, as, once formed, they may render the area covered impassable by any but the lightest traffic for long periods. Thorough drainage of an area after flooding is slow and the construction of causeways involves a vast amount of material and labour.

3. In 1914 the Belgians flooded the valley of the River Yser from Dixmude to Nieuport by holding up the river water at the sluice gates as the tide fell and allowing the sea to enter as the tide rose. An area eight miles long and four miles wide was thus placed under water to a depth of two to three feet, the difficulty of crossing being much increased by the numerous ditches used for drainage in normal times. This obstacle prevented serious attack across it during the rest of the war.

4. Accurate information may be collected from civil records regarding the levels of rivers and canals and the probable effect of inundations on the surrounding country in the neighbourhood of a proposed defensive position. The possibility of inundations is one of the many points of engineer

information which should be considered when military reconnaissances are being carried out.

5. Inundations on a large scale call for highly technical work, the details of which are beyond the scope of this volume.

Inundations on a small scale can sometimes be formed in front of a line when a position is occupied near a stream. The most favourable sites for forming small inundations are those where the bed of the stream has only a slight fall, the sides of the valley being regular and rising rather abruptly ; where these features do not exist, the work must generally be on a large scale.

6. The difficulty of crossing an inundation can be greatly increased by cutting ditches of sufficient depth chequerwise through the ground to be inundated and digging deep pits before damming up the stream ; a trench-plough would facilitate this work. Wire, etc., may also be used with advantage.

34. Camouflage and concealment of defence works

1. The principles and application of camouflage to active service conditions are given in the Manual of Field Engineering, Vol. II, 1936, Chapter VIII. These principles hold equally good for works executed in peace, but as the conditions are different, the application of the art has to be varied to suit them.

The principal points of difference are that under peace conditions neither labour nor money are likely to be available to provide that constant attention to upkeep, painting and altering of material to suit the seasonal changes which is possible during a war. In addition, it is almost certain that, in spite of all precautions to prevent it, enemy agents will be able to observe works at close range ; simulation of natural or local objects by means of painting is therefore impracticable and would be more likely to call attention to something of military importance which might otherwise escape notice.

2. *Concealment during construction of works.*—Concealment must therefore be sought in making, so far as is possible, the construction of all military works appear to be part of the ordinary civil building and engineering works of the locality, or, failing this, by the rapid construction and covering of works in such a way that they will not be exposed. Thus a heavy gun platform constructed in the vicinity of houses can be effectively concealed by the erection of a light building over it (Plate **26**). A small defence work constructed on the principles explained in Sec. **17**, 2, in a field or in quite open country will have little to give its position away, if the

machine gun embrasures, tunnel openings, etc. are filled in with earth, which will become covered with grass and vegetation after a short time.

3. Plantations for the total concealment of large defence works in the fighting zone, and of depots, engineer parks, etc., in back areas, are not a practical proposition, as their location must inevitably be discovered by enemy agents. Much work of value may, however, be done in peace by the judicious planting of suitable trees and hedgerows. After a few years groups of trees will give complete cover from both air and ground observation, will not interfere appreciably with fire and will afford a very useful anti-tank obstacle. Orchards, in which trees are planted in regular formation, are particularly useful for such a a purpose. Plantations of this description can be advantageously made on the zones occupied by the defence works, while the ground which the attackers will occupy should be left as bare as possible. Hedgerows, combined with small woods or tree clumps, will assist in permitting of covered approach from the rear and will also cover positions of artillery. Care should be taken to ensure that trees are not planted in situations where, when grown, they will obstruct the trajectory of fire from artillery positions or the field of fire from the defence works.

35. Defence schemes and maps

1. When it has been decided to organize and construct a permanent defence system, the first step is to work out in advance a carefully prepared defence scheme. This scheme should be drawn up on the lines laid down in Field Service Regulations, Vol. II, 1935, Chapter IX, and should contain all particulars to which reference is made therein. In addition to the actual lay-out of the fighting area, with its defence works, artillery positions, machine-gun posts, look-outs, command posts, etc., a complete picture of the whole fortified zone is necessary. The administrative appendices should include the sites of, and details concerning, all depots, hospitals, aerodromes and establishments of every kind, together with the necessary rail and road communications.

2. It is also necessary to have a detailed appendix to the defence scheme showing exactly what work is to be done in peace and what additions and extensions are to be completed after the outbreak of war. The order of priority of the work must also be clearly laid down. Maps showing the various stages of construction should be prepared, and projects got out from all the works proposed with estimates of time, labour and cost. Well-concerted measures for obtaining the necessary labour and material for work to be constructed after

hostilities have begun must be devised and recorded in the scheme. Such work would include the demolition of buildings and of woods and hedges, where necessary, and also the preparation for defence of towns, villages, farms, etc., where they lie within the defensive zones.

3. It is also important that provision should be made in advance for a supply of maps for use in war. These should include small scale maps of a high order of accuracy for command and artillery use, covering not only the defensive area but the whole of the ground within artillery range of the outer defence line. Larger scale maps of sectors showing details of defence works, the underground system of tunnels and dug-outs, communication trenches, overland routes, etc., will be required in large quantities for the use of the troops in the line.

Artillery fighting maps will be prepared for each observation post, battery position and artillery brigade headquarters, which will show the position of observation posts and guns and the natural features of the country over which the enemy can operate.

4. *Revision of the defence scheme.*—Since changes will occur in the topography of the defence area owing to the new construction of roads and buildings and the planting of trees, etc., it is essential that the defence scheme and maps shall be revised and brought up to date at least yearly. Further, it will be necessary to enter up any items of defence work that may have been constructed as part of the peace programme.

CHAPTER V

PERMANENT FORTIFICATION—DESIGNS AND DETAILS OF STRUCTURES

36. Concrete work for resistance to shell fire

1. *Materials.*—Earth has little power of resisting the penetration and destructive effects of heavy shell, unless it is in great depth. Hence, although a minimum depth of 30 to 35 feet in ordinary soil, or of rather less in rock, will provide adequate cover in the case of tunnel communications or deep dug-outs, earth is chiefly used in permanent work for concealment rather than for the building up of breastworks or parapets.

Well-made brickwork, if of sufficient thickness, has good power of resistance, but it will crumble and disintegrate under continuous fire. Its use, therefore, will usually be confined to interior work for the lining of magazines and parti-walls in dug-outs. The glazed variety is preferable to plain burnt brick, being more easily washed after gas contamination.

2. Concrete and steel are the best available materials for giving protection. The combination of the two in the shape of reinforced concrete forms the basis of nearly all modern shell-proof construction. Hardened steel plate is used for gun-shields, cupolas and roofs of battery commanders' posts and observation posts, and in certain cases for the embrasures of light guns and machine guns. Plain concrete requires greater thickness for the same amount of protection as compared with reinforced concrete, but the uneven vibration of the rods and concrete inherent in the latter is avoided. All concrete structures for resistance to shell fire should be built on the monolithic system rather than on the concrete block system, which has not the same amount of strength and cohesion.

Block construction may be useful in certain circumstances, when it is desired to erect a number of machine gun emplacements, etc., of similar design when little time is available, but even then, provided that templets are available, construction by means of rapid hardening cement can be completed almost as quickly.

3. *Proportions for concrete.*—The following are suitable proportions by volume for the P.C. concrete :—

For mass work (foundations, etc.), 1 cement, 2 fine aggregate, 5 coarse aggregate.

For reinforced concrete, 1 cement, 2 fine aggregate, 4 coarse aggregate. If, however, the work is to be carried out under active service conditions, it would be better to make the proportion 1 : $1\frac{1}{2}$: 3, in order to allow for unskilled workmanship and supervision.

The nature of the aggregate is often largely governed by the materials obtainable locally. It should be carefully selected, and be hard and free from loam, dirt or vegetable matter. Angular fragments or rounded pebbles, such as Thames ballast, may be used, the latter being easier to consolidate but requiring more cement.

The stone for the coarse aggregate should pass through a $1\frac{1}{4}$-inch ring. Fragments smaller than $\frac{3}{16}$ inch should be separated and classed as fine aggregate. Clinker, slag or breeze should not be used in this class of work.

The fine aggregate should consist of clean pit or fresh-water sand or the fine screenings from the coarse aggregate.

The quantity of water for mixing the concrete should be between $5\frac{3}{4}$ to 7 gallons per 100 lb. of cement or from $32\frac{1}{2}$ to 40 gallons per cubic yard of concrete. The slump on a 4-inch to 8-inch cone, 12 inches high should be about 3 inches.

4. *Special concrete.*—In order to obtain a particularly hard surface for resistance against the direct impact of projectiles, such as on the massive of a concrete mass redoubt as in Plate **15**, or on the front face of an emplacement, as in Plate **12**, special care must be taken in the selection of the materials and of the mixture, so as to produce the maximum of hardness and density. The mixture should be such as will provide an essentially workable mass, which, when laid and well rodded, will produce a dense and homogeneous concrete with no air spaces. Slow setting should be encouraged by keeping this special concrete damp for at least three weeks. In the case of a flat surface this may be effected by ponding, *i.e.* building up small walls of clay and filling with water, and in other cases by covering the surface with sacking or other water-retaining material, which must be constantly wetted.

Good results have been obtained by adding a small proportion of steel filings to the fine aggregate, and the hardness of the surface can be intensified by the addition of 15 per cent. of silicate of soda solution to the water. (For further details on the mixing and laying of concrete, *see* the Manual of Field Engineering, Vol. II, 1936, Chapter VII.)

5. *Principles of construction.*—The effect of H.E. shell fire on reinforced concrete varies so greatly that the strength of the material required to resist it cannot be definitely calculated on the lines of a civil engineering formula. Reliance has to be placed on the effects actually produced by bombardment in war or by means of carefully conducted experi-

ments in peace. The great expense of the latter has resulted in very little having been done in this way, so the data derived from structures subjected to heavy bombardment during the Great War must form the basis of present conclusions. It is, however, essential for the military engineer to look ahead, and in all designs it is necessary to take into account what ordinary developments in the future weight and power of destructive weapons may be expected.

The following principles are based on the observation of structures under actual fire :—

i. A strong steel reinforcement of round rods or expanded metal should be placed within six inches of the outer surface of the roof or wall to assist in resisting the impact of the projectile and the tensile stresses due to impact.

ii. A similar reinforcement should be placed within two or three inches of the inner surface of the roof or wall to resist tensile stresses in the concrete, to localize fractures and distribute the shock, and so obviate the danger of large pieces being detached and injuring the occupants.

iii. Each of the layers of reinforcement referred to in (i) and (ii) should, if composed of round rods, be made up of a grid of bars at right angles to one another.

iv. The two layers should be maintained at the correct distance apart by forked steel distance-pieces, suitably spaced and firmly bound to one another by strong, annealed wire.

v. The rods in the reinforcing grids should be about $\frac{1}{2}$-inch in diameter and so spaced as to form squares with sides of six and nine inches, the rods being wired together wherever they cross.

vi. Reinforcement against shear should be provided in the form of numerous stirrups of $\frac{1}{4}$ to $\frac{5}{8}$-inch in diameter, looped round the bars of one layer and hooked round those of the opposite layer. These stirrups should not be at a greater distance apart than nine inches.

vii. In the case of a roof over 3 feet 6 inches thick an intermediate layer of steel should be placed midway between the other two layers.

In this case the outer layers will each be connected to the central one by a separate system of stirrups.

viii. The sectional area of steel in each grid and in each direction should be about 2 per cent. of the corresponding sectional area of concrete ; all steel in stirrups is additional to this amount.

ix. A composite roof is best for providing protection against a heavy and continuous bombardment. This consists of a sand course intended to turn up and deflect shells arriving at an angle, a bursting course either of concrete or hard pebbles to cause the shell to detonate, next a cushion of sand to absorb the shock and to distribute the explosive effect of the shell, and under this a reinforced concrete mass (main roof) to resist the penetration and burst of a shell with a delay action fuze or an A.P. head. The main roof rests normally on standard steel troughing bolted to vertical steel rods forming part of the reinforcement, which prevents the flaking off of pieces. Supporting girders may be a necessary addition in roofs of wide span, or, alternatively, complete girder construction may be resorted to.

The above is the simplest form of composite roof, and it possesses the great advantage of comparatively easy repair after damage from a bombardment.

A rather more complicated form of composite roof has a separate distributing course of rails, with a lower cushion of sand between it and the main roof. An air space (double roof) may also be substituted for the upper sand cushion, *i.e.* above the separate distributing courses, but this involves certain structural difficulties as the outer roof must be supported independently of the main roof.

x. Table of thicknesses in standard composite roof:—

Item	Material	Proof against		Remarks
		8-inch	6-inch	
Concealment	Earth ..	6 in.	6 in.	Planted with rye grass etc.
Deflecting course.	Sand ..	3 ft.	2 ft.	—
Burster ..	Reinforced concrete.	2 ft. 6 in.	1 ft.	Hard pebbles may be used as a substitute —in depth 6, 4 and and 2 ft. respectively.
Cushion ..	Sand ..	4 ft.	3 ft.	—
Main roof ..	Reinforced concrete.	4 ft. 6 in.	3 ft. 6 in.	—
Support* ..	Standard steel troughing.	—	—	Or girder construction. *See* sub-para. ix, above.
Total	.. .. ..	14 ft. 6 ins.	10 ft.	

* Weight 40·5 lb. per sq. ft. of area covered.

xi. Under certain conditions it is not practicable to construct roofs of the composite type described above. This is particularly so in the case of machine gun emplacements or observation posts, the apertures of which have to be above ground level for purposes of fire and observation, but which must also be kept as inconspicuous as possible. For these it is necessary to provide reasonably safe cover which shall not project unduly above the ground. A thickness of $3\frac{1}{2}$-feet reinforced concrete is the minimum for such construction, this being proof against the occasional 6-inch shell or light air-bombs.

Steel may be used as an alternative for the roofs of observation posts, etc., either in the form of a cupola or plate. The proof thicknesses of armoured plate against the different weights and natures of projectiles are regarded as secret, and cannot therefore be given in this manual. The information can be obtained from the Experimental Establishment, Shoeburyness.

xii. The sides and floors of all shell-proof structures must not only be of adequate strength to carry the weight of the superstructure, but in addition they must be able to withstand the blows of shells piercing the ground and detonating against or under them. All floors should be substantially reinforced and the reinforcing bars carried round all angles up to the side walls.

NOTE.—The DORPVELD REDOUBT, which was one of the smaller works in the defensive girdle of ANTWERP, was disintegrated after four days' bombardment (29th September to 2nd October, 1914), largely through the failure of the floors and foundations to withstand the detonation of howitzer shells fitted with delay action fuses and bursting under them.

37. Casemates and cupolas

1. *Casemates* (Plate 9).—These are the most simple form of shell-proof construction, consisting of a closed compartment with a loophole or opening for fire, observation or light projection. A somewhat restricted field of view or fire is inevitable in such construction, according to the size and shape of the opening and the thickness of the wall containing it. This drawback, however, is of minor importance in an element

which is essentially for use in a flanking position, where the direction of fire is in general well-defined and determined. The casemate is not a good form of construction for a front position, since the loophole or embrasure will be open to direct fire, which may cause premature destruction to the casemate and its equipment. A casemate takes the general form shown in Fig. 1 on Plate 9. Of its four sides, AB, AC, CD, BD, the three former can be of any thickness desired and they can be further protected by earth cover, etc., while the side BD can only have a limited thickness, since it contains the loophole opening with its requirements for fire and view. It is essential, therefore, to protect this face as far as possible against hits which may put the casemate out of action. Thus, if the field of fire is contained within the angle EFG (Fig. 2), all projectiles arriving within the angle EFH can be met by a concrete abutment or cheek constructed in this space and forming an extension of the casemate.

If a group of casemates are to be built with a field of fire in approximately the same direction, each casemate can be made to protect the one adjacent to it (Fig. 3). The casemates may contain equipments of the same nature, such as a section of machine guns, or some may have guns, others searchlight projectors, etc. The protective cheeks limiting the field of fire, AB, CD, . . . need not necessarily be parallel. When some of the casemates are very small (for flank observation posts, light machine guns, etc.), it is possible to omit the partition wall. Finally, if the set of casemates is built on a slope (preferably a reverse slope), the advantage of different levels will be gained, which will ensure better protection and increase the difficulty of accurate ranging to hostile artillery fire, as in Fig. 4.

2. *Loop-holes.*—A loop-hole or embrasure should be as small as possible to diminish the probability of a hit, but on the other hand it must allow for the free movement vertically and horizontally of the weapon installed. Since the wall containing the loop-hole is of a certain thickness, it is necessary to splay the loop-hole, either towards the interior or the exterior. There are three ways of doing this :—

i. A narrow opening on the outside, splayed vertically and horizontally towards the interior (Fig. 5). This type of loop-hole, having the smallest possible dimensions on the enemy's side, offers the minimum of visibility and vulnerability.

It is the most useful form for a light gun or machine gun on a fixed mounting ; but it will be found that the thickness of the wall is a limiting factor.

ii. A narrow opening inside, splayed vertically and horizontally towards the exterior (Fig. 6). This form of loop-hole is much more visible and vulnerable than type (i). Further, its funnel shape assists the entry of bullets or projectiles. This drawback can be lessened by stepping off the outside (Fig. 7), which will present a vertical face against the impact of bullets, but this device will do little to prevent damage from shell, though it will stop many shell-splinters.

It is chiefly useful for light machine guns or guns on field carriages, or for searchlight projectors.

iii. A narrow opening in the middle with splays on the inside and outside.

This can be used in a comparatively thick wall, and is a compromise between types A and B, being somewhat more visible and vulnerable than A and with less facility for easy manipulation of the gun in equipment than type (ii) (Fig. 8).

3. *Use of armour plate.*—A loop-hole of the type, as in para. 2, i, above, is the simplest and best form of loop-hole for general use, but it imposes certain limitations to the thickness, *i.e.* the shell-resisting property of the wall. This introduces the idea of replacing the outside wall of concrete by one of steel. By making use of this expedient, it is possible to have a comparatively thin wall of armour plate equal in strength to a massive wall of reinforced concrete, and in which convenient and safe loop-holes or embrasures can be inserted.

Alternatively, a loop-hole plate can be built into the concrete wall, which will be an effective and somewhat cheaper method of overcoming the disadvantages inherent in a loop-hole cut in a thick wall.

NOTE.—Loop-hole shutters. All loop-holes should be fitted with a steel shutter, which will completely close the aperture when the weapon or equipment is not in use. This shutter should be of definitely gas-proof pattern and can take the form of a dead-light with air-tight rubber rings.

4. *Cupolas* (Plate **10**).—The cupola is a development of the armour-plate-fronted casemate, being made entirely of steel, and so eliminating the material drawback of a structure which is in part metal and in part reinforced concrete.

It possesses the great advantage of affording a field of fire all round the horizon, since the cupola with its gun and detachment can be made capable of being revolved through a complete circle. A cupola can be used for any nature of equipment, *e.g.* for semi-automatic, anti-tank or anti-aircraft

guns, for one or more machine guns or for a searchlight projector.

It is contended that there is a great risk of a cupola being jammed and put out of action by a direct hit or by the blocking of its racers by fragments of concrete or shell splinters. These are risks which have to be accepted in view of the many advantages offered by this method of getting direct fire all round with good protection for man and weapon. But even these risks can be minimized by the use of armour plate heavy enough to withstand a direct hit from shell up to a certain calibre, and by the provision of a belt of armour set into the concrete round the base of the cupola and acting as a curb against the entrance of splinters between the cupola and its seating.

Cupolas can be placed in three categories, having reference to the position of the weapon or equipment installed :—

i. The muzzle and chase are permanently outside. This arrangement allows for the minimum size of cupola. It has therefore the advantages of economy, affords a smaller target and offers a better resistance for a given thickness of armour plate. It has the disadvantage of the constant exposure of the gun to hostile fire, with the risk of premature destruction. This is the normal type of naval turret mounting and is chiefly of service in land forts for anti-tank or anti-aircraft armament.

ii. The gun is withdrawn within the cupola when not in action, and the chase and muzzle exposed for firing.

This arrangement reduces the chances of the gun being destroyed when not in action and enables a gun with a long barrel to be protected within a cupola of reasonable weight and dimension. It is chiefly useful for a light gun of the high velocity type.

iii. The gun is permanently within the cupola. In this case protection is afforded at all times to the gun and its mounting, but the cupola is necessarily heavier and more expensive than types (i) and (ii). The advantage of complete protection for gun and detachment is an undeniable asset and has caused this type of cupola to be generally adopted. The normal equipment for this type of cupola are howitzers or short-barrelled guns, which are often mounted in pairs. Two examples are shown on Plate **10**, both being standard designs of the firm of Vickers-Armstrong.

Note.—Types (ii) and (iii) are usually made on the disappearing principle, so that the complete cupola can be raised, lowered and revolved in the concrete shaft, in which it is fitted.

38. Concrete posts for machine guns

1. *General remarks.*—These may be of varying design to fulfil the purpose for which they are intended and to suit a particular site.

They will normally consist of a closed-in casemate for one or two guns, built as small and compact as possible. The command should be kept low for purposes of concealment, and in some cases the casemates may be completely buried, as, for example, in a railway embankment or in the bund on a river bank. No standard type can be laid down, as sites and conditions differ so much, but certain fixed dimensions for the table to take the machine gun mounting, the size of the loophole and adequate space for the handling of the gun must be provided for in the design. Good ventilation is essential, or the gases produced by firing may render the emplacement untenable.

2. *Types.*—Plate **11** shows a single-gun emplacement, which is a good type for use in a redoubt or defended post. It is fitted with a double-splay loophole with crenelations on the outside to guard against the entry of bullets or shell splinters. Very careful arrangements are necessary to ensure the carrying off of carbon monoxide fumes generated by firing. If the muzzle of the gun when fired projects beyond the outer edge of the loophole, this trouble does not arise, but, when it is within the outer edge, the chamber will, after continuous firing, be so filled with this gas as to affect the personnel seriously, and the air vents shown in the plate will not in such cases be effective in removing it. The following device has been found to effect a complete cure of the trouble, and it should always be provided when the thickness of the walls of the casemate is such as to make it impossible, or even difficult, to project the muzzle of the gun outside the edge of the loophole : A removable metal sleeve is made to fit over the outside of the barrel and water jacket and to project a few inches beyond the muzzle. It is not necessary that this sleeve should project outside the loophole. The action is that the discharge causes a vacuum inside the sleeve, which draws in air from the rear. The powerful forward blast of air so caused results in blowing all gases out of the loop-hole.

Plate **12** shows an alternative design for a two-gun emplacement, which can be made fairly inconspicuous where natural cover or a good background are available. It is also a suitable form of construction for the cellar of a ruined house or inside a cottage or farm building. The dimensions shown in the section AB are correct for the present pattern of Vickers gun on a muzzle-pivoting mounting. A pair of such emplacements, connected to a mined dug-out in rear, form

a practical defence unit for covering an area of dead ground, or the interval between defended posts or small permanent defence works, in the intermediate zone (*see* Sec. **17**, 2).

A somewhat different design is required for the concrete posts or blockhouses in the forward zone, or screen, of a defended area. It is necessary that these shall be to some extent self-contained in the way of supplies and ammunition and capable of a protracted defence in the event of being isolated. As it is also desirable that good observation be obtained of the country in front, it may not always be possible to keep these structures low and inconspicuous. It is therefore necessary to design something that will fulfil the objects stated above, and also be of sufficient strength to stand up to a direct bombardment from guns mounted in tanks and from field artillery.

Plate **13** shows a two-storied concrete blockhouse which is designed for this purpose. In the main compartment are two machine guns mounted on cone mountings, firing through loop-holes at ground level. A fitter's bench and lockers for spare boxes of ammunition are also provided. Above this is a chamber with loop-holes for close defence either by bombing, light machine gun or rifle fire. A reinforced concrete ladder leads to the platform above, whence observation is obtained through a shaft in the dome of the building. This shaft is closed by means of a heavy steel scuttle, which, when raised, acts as a cupola to the observation post. Underneath the machine gun floor is a dug-out for the detachment, with bunks in tiers, ration store and water supply. Fresh air is piped from a considerable distance in rear to avoid local gas contamination, but on entering the blockhouse it is connected to a decontaminating filter by means of a by-pass, through which the air can be passed if necessary. As regards the protective measures against shell fire incorporated in this design, it will be noted that there are no loop-holes or openings in the front, which is protected by a " massive " of concrete six feet thick. This concrete is of special shell-resisting composition (*see* Sec. **36**, 3), and the surface is made very smooth, so that the probability of a projectile glancing off it is increased.

Entrance into the blockhouse is by means of a window opening in rear, reached by means of a light ladder which is pulled inside after use. The opening is closed by a loop-holed steel shutter.

Frontal defence is normally provided by the flanking fire from machine-guns in the blockhouses to right and left, but in case of close attack or assault the blockhouse is defended by means of fire and bomb-throwing from the upper storey platform.

Isolated posts of this nature should be girdled by a belt of heavy wire, outside which will be lines of anti-tank mines and obstacles.

39. Defended posts

1. Defended posts (Plate **15**) form the basis or groundwork of any area of land organized for protracted defence, and they are the essential framework of the intermediate zone, as described in Secs. **16** and **17**. They may be said to act as barriers or reefs, against which the waves of the assault are split and broken up. Consequently they must be strongly armed, fitted for all-round defence and capable of withstanding a severe and continuous preliminary bombardment. The garrison of a defended post should consist of a complete unit of infantry, which will provide detachments for the machine guns, sentries and look-outs, with an adequate reserve for counter-attack. A detachment of engineers will be required where electrical plant exists for providing light and power, and some artillery personnel in the event of the installation of anti-tank or anti-aircraft equipments.

2. Defended posts may be formed in a quarry, a farmhouse or a village or wood, where such occur within a defensive area, and which it is desirable to hold. Such localities, however, will certainly draw fire when occupied or fortified, and it is usually preferable to build inconspicuous posts apart from such obvious targets. Villages, houses, etc., have the inherent advantages of affording cover from view, and the masonry walls will act as bursters and afford certain protection, especially if there are cellars, which can be strengthened for occupation. Tactical considerations may make it imperative to include a village or group of buildings or a wood in the defensive system, and in such a case the principles and methods of preparation laid down in the Manual of Field Engineering, Vol. I, should be followed. For the most part, however, defended posts will have a better chance of surviving bombardment and of fulfilling their proper role in a defensive zone if they are constructed on favourable tactical features of the natural ground and every device and precaution made use of for their concealment from the ground and air. Villages left unoccupied should be destroyed to prevent the enemy establishing himself in them.

3. The main requirements of a defended post are :—

i. Concealment.
ii. Facilities for flanking fire.
iii. All round view and defence.
iv. Efficient communications.
v. Protection against bombardment.

vi. Protection against gas.
vii. Facilities for counter-attack.
viii. Reserves of ammunition, food and water.
ix. Essentials for health and administration.

4. *Concealment.*—i. *Siting.*—The choice of site for a defended post is limited to some extent by the tactical requirements of the defensive area as a whole, since each work forms a link in the chain and must be capable of supporting by fire the adjacent works on its flanks. Careful reconnaissance will, however, often enable this essential condition to be fulfilled, coupled with the advantages of a good position for all-round defence and concealment from view.

In low-lying or level ground the concealment of a work even from ground observation becomes a difficult matter and can only be achieved by making use of natural cover such as a thickset hedge or orchard, or by artificial planting. In hilly country, or where the terrain is featured or undulating, the problem is an easier one, and it is possible to take advantage of a reverse slope, where the ground is, at any rate, out of view from the enemy lines. Such a site must have a really good field of fire to its flanks covering the intervals, a reasonable if somewhat restricted field of fire to the front and a clear space in rear for purposes of all-round defence. If these conditions are fulfilled, the site may be regarded as an ideal one for the purpose, and it remains to construct a work which will not betray its existence to air observation.

ii. *Camouflage.*—The essential condition to fulfil is to adapt the lay-out and design of the work to the terrain, and to do as little as possible to alter the natural appearance of the ground and its surroundings, as seen from the air or by ground observers. The elements which have to show above ground, *e.g.* the openings of machine-gun emplacements, observation posts, tops of searchlight shafts, sally-ports, etc., should be kept as inconspicuous as possible and camouflaged with growing bushes and herbage. Further, all such elements should be concealed from frontal view by natural features in the ground or, where none exist, by flat artificial banks. When the post is definitely sited on a reverse slope, there is no occasion to expose any openings to the front, with the exception of one or more observation posts for direct observation.

5. *Facilities for flanking fire.*—The development of a heavy and well-directed fire to either flank by means of machine guns concealed from the front is the guiding principle in planning a defended post. The machine guns will be echeloned back on each flank, so as to command all the

intervening ground between the work and those to its right and left. In other words, in order to avoid the grave risks of having machine gun openings facing the front, each defended post will be largely dependent on cross fire from the adjacent works for its defence against frontal attack. Thus it is of supreme importance to make this flanking fire as infallible and efficient as possible. This can be achieved by the construction of very strong and well-sited emplacements, the fire from which will be assisted and intensified by carefully aligned tactical wire.

6. *All round view and defence.*—A defended post must be capable of an efficient all-round defence, in case of isolation. A good view in every direction is the first essential. Direct view from observation posts must be supplemented by periscope openings. The latter can be made at any point designed by means of pipes driven up from the combat gallery, and by this means it should be possible to limit the dead ground in the vicinity of a work to a minimum. All-round fire will be developed to the flanks and rear by the machine guns of the main armament, as well as by indirect fire from the trench mortar, while the immediate front will be under close fire from light machine guns and/or bomb-throwers from the sally-port openings. In some cases it may be advisable to build a concealed machine-gun emplacement directly in front of the work, which can be unmasked and used on emergency. Such an arrangement is, however, not indicated in the type drawing on Plate **14**, since it is not a normal provision.

A ring of defensive obstacles will surround the work. This will usually take the form of one or more belts of barbed wire entanglement, each of which should be at least 20 yards in width, protected on the outside edge by anti-tank obstacles or mines. Openings must be left for requirements of counter-attack. It should be remembered that regular belts of wire will show up clearly in air photographs, so the general effect should be made as irregular as possible and the whole entanglement blurred by sowing grass or vetch. For this reason, too, a low spider wire entanglement or inconspicuous steel pickets has the advantage of concealment, though it does not make such a good obstacle as normal high wire.

7. *Efficient communications.*—The communications in a modern defended post will be entirely under the surface of the ground in the form of galleries or subways. The most important of these is the combat or upper level gallery, which links up the surface elements, *e.g.* machine gun emplacements, observation posts, sally-ports, etc., and which gives covered access to all parts of the work for purposes of command and

administration. Leading off this gallery are the combat dug-outs and the S.A.A. and bomb stores, and the entrances to the machine gun emplacements, command posts, searchlight and mortar shafts. It is essential that this gallery shall be of simple design, so as to allow of quick and unimpeded movement. A main gallery leading from the rear (protected entrance) to the front (forward observation post) with branches leading off to the groups of machine gun emplacements with their combat dug-outs, etc., in the best and simplest form of lay-out. This is shown diagrammatically in Plate **14**. The upper level gallery cannot normally be at any great depth below the surface, since immediate access to machine gun emplacements and sally-ports is essential, and consequently the rise from the gallery to such surface elements must be attained by a short flight of steps or an easy ramp. Thus there will not be as a rule much depth of earth cover over the combat gallery, and concrete construction will be necessary for obtaining shell-proof protection. Good lighting and ventilation are essential provisions. The former will normally be by electric light and the latter by fans, run off the plant installed in the lower level workings, which will be described hereafter (*see* para. 12, i and iv, below).

Galleries or subways for use as communications must be large enough in section to allow of the free movement of fully armed personnel and for the easy conveyance of ammunition and stores. Labour and material make it imperative to keep the dimensions within the smallest limits compatible with service requirements. The following dimensions should be regarded as a minimum :—

Main gallery	6 ft. 4 in. × 4 ft. 0 in.
Branch gallery	6 ft. 4 in. × 2 ft. 9 in.
Adit to observation posts, etc.	4 ft. 10 in. × 2 ft. 9 in.

In addition to the above, passing places should be provided at intervals in main and branch galleries, and widenings arranged at junctions and crossing points.

8. *Protection against bombardment.*—The attack on any prepared position will normally be preceded by an intense bombardment as a preparation for the advance by infantry and tanks, and, further, at any time during static warfare, a defended post may be subjected to harassing fire from all natures of artillery up to the largest. Men and material must therefore be afforded the maximum of protection possible, in order that the fighting strength and resources may be as little impaired as possible for the decisive action.

The value of concealment has been already dealt with in this section, and it must be emphasized that, since artillery fire or bombing is much less effective in the absence of obser-

vation and registration, the absence of any conspicuous landmarks or disturbance of the ground to give away its position will go a long way towards rendering a defended post immune from an accurate and devastating bombardment.

i. *Combat level.*—As regards material protection, the surface elements, which are the machine gun emplacements, upper level gallery, combat dug-outs, etc., will be constructed in reinforced concrete of the type and thickness described in Sec. **36**, 2, while use will be made of armoured plate for the roofs of observation posts and the covers of shaft openings. It may not always be possible to provide the maximum thickness in the roofs of machine gun emplacements without making them dangerously conspicuous, since it may be necessary to keep the openings high up for a good field of fire, but the walls and floors can, and should, be made definitely shell-proof. This refers especially to the walls on the side exposed to frontal fire. The vulnerability of the floors of all surface elements against shells fitted with delay action fuzes, which may penetrate the ground at such an angle as to miss the wall and burst underneath the floor, must be always borne in mind in designing works of this nature.

ii. *Lower level.*—Accommodation for personnel at rest or in reserve, the signals office, main magazine, engine room and stores will normally be provided in deep dug-outs, and these will be at such a depth as to make them definitely shell- and bomb-proof. Communication to the upper or combat level will be by means of flights of steps, of which three or more should be provided. A typical arrangement for a dug-out system of this nature is shown in the section on Plate **14.** In swamps or unsuitable ground it may be impossible to dig down to a sufficient depth to ensure protection, and in such a case reinforced concrete construction must be adopted, as in the case of the combat dug-outs. But such an arrangement is not a really good one, since no real rest or freedom from noise and shock is possible in a dug-out near the surface. Thus it may be said that a site where deep workings are impracticable is a bad location for a defended post, if there is any possible alternative.

9. *Protection against gas.*—It is hardly a practical proposition to protect all the surface elements from the ingress of poison gas, since the machine gun and observation post openings can seldom be closed, and so the upper level galleries will be infected in time. The combat dug-outs should, however, be fitted with gas-proof curtains and, if the general lay-out is a simple one, it may be possible to shut off the section of the main gallery which includes the stairways leading down to the lower level. It must be remembered,

however, that the introduction of too many curtains in the main gallery may be a menace to free movement in case of emergency.

The deep dug-out system can, however, be kept free from gas contamination by carrying into effect the principles laid down in Sec. **22**, 3. The main requirements are a constant supply of pure air causing a positive pressure against the ingress of noxious gas, when gas curtains are lifted, and a shifting lobby and storage for clean clothing at the entrance. This can be conveniently led off the air lock, as shown in Plate **14**. The supply of fresh air should, if possible, be brought from some distance away from the work, thus avoiding contamination through local gas discharges or from gas shells. Where the defended post is connected to the rear by a tunnel, fresh air can be conveniently brought this way in a pipe or conduit. The installation of a filtration plant or some means of decontaminating the air must, however, be provided, as freedom from gas cannot always be guaranteed wherever the inlet is located. Where power is available within a work, whether from its own dynamos or from outside supply, forced draught will ensure the flow of pure air throughout the dug-out system, with the essential positive pressure referred to above. In other cases an efficient system of ventilation must be devised by means of extractor shafts, the operation of which can be greatly assisted by the installation of a Cornish stove, or small enclosed fire, to draw in fresh air and cause an up-draught. (*See* Manual of Field Engineering, Vol. II, 1936, Sec. **26**, 6.) In the use of these adequate means must be provided whereby all the air can be directed by means of a by-pass through a filter before entering the galleries.

10. *Facilities for counter-attack.*—It is essential to provide some easy means of egress, *i.e.* sally-ports, from within the work for purposes of counter-attack. Such openings should be well concealed from view and must be fitted with some kind of movable barrier which can be closed against penetration. Loop-holed steel doors, opening outwards, form the best permanent stop. The galleries leading to such can be further protected by a dog-leg with a loop-hole commanding the entrance and by a deep hole normally covered by a wooden platform or planks. Sally-port openings can be designed to serve as bombing-shafts for light mortars or hand-throwing, in case of close attack. In the typical design on Plate **14** these are shown as B.S.S.P.

Gaps in the defensive wire surrounding the work are an essential provision in considering facilities for counter-attack.

11. *Storage for ammunition, food and water.*—An adequate reserve of war stores, food, etc., must be maintained within a

defended post and these should be housed in dry, shell-proof compartments. Expense magazines for S.A.A. must be adjacent to the machine-gun emplacements, and bomb-stores within easy reach of the bomb-shaft openings. In the typical design these are combined as S.A.A., and bomb-stores, and adjoin the combat dug-outs. Where heavy mortars or anti-tank guns are installed, expense magazines will be required alongside the emplacements. Reserve ammunition of all sorts will be stored in the main magazine in a deep dug-out in the lower level, and this should have a special stairway or lift connected with the combat level.

Stores for rations, equipment and spare parts can be located at any convenient place for distribution, usually on the lower level. The R.E. store will be best placed at the rear end of the combat gallery near the protected entrance, where bulky stores such as coils of barbed wire, etc., can be handled without causing blocks or congestion.

A good water supply is vital. Tanks to hold an adequate reserve for all needs will be installed and the source of supply should be, if possible, from a well within the work. Failing a well, a piped supply in a shell-protected pipeline is desirable, which should be led along a subway, if this exists. Pumps, either machine-driven or hand-operated, should be installed to enable water to be used under pressure for cleansing and decontaminating purposes.

12. *Essentials for health and administration.*—Apart from the basic necessities of life, such as pure air, food and water, some degree of comfort is necessary to keep the garrison of a defended post in fighting trim. One of the main considerations is proper rest for personnel not actually standing to or on duty. No surface shelter, however thick its roof and walls, will afford proper rest and freedom from noise and vibration during long hours or, maybe, days of continuous bombardment. A deep-dug system of accommodation under an effective depth of earth is the only solution. In addition to the actual sleeping compartments, which should be fitted with tiers of bunks, a cook-house, ablution-room and latrine are essential accessories. The provision of a dining-room and a drying-room for wet clothing will add greatly to the comfort of the men without unduly increasing the cubic space occupied. The latrine should be kept as far away as possible from the sleeping quarters and specially ventilated by means of an up-draught shaft.

i. *Ventilation.*—Efficient through-ventilation is essential both for the comfort of the troops and for keeping the accommodation dry. This is a most important point to consider in designing the general lay-out of the deep level

system, or pockets will form where damp and foul air will collect.

ii. *Surface drainage.*—All floors should be laid with a gentle slope leading to surface channels, connected to a main channel and sumps. Arrangements will be made for discharging the sullage water from sumps and for getting rid of grease and solid matter.

iii. *Water supply.*—Water should be laid on to the cookhouse and ablution rooms and taps provided for filling water-bottles at convenient points. Stand-pipes will be provided in barrack rooms and galleries, so that water for hosing down all floors and walls will be available.

iv. *Lighting.*—Oil lamps or candles are unsatisfactory, as they exhaust the air and require frequent attention. Electric light is the only practical means of illumination for both the combat and deep levels. Electric power can be obtained from outside sources or from a small plant installed within the work. The former method envisages the installation of a central power station, supplying current to a group of defence works, with the advantage in economy of operating staff, as compared with the running of separate plants in each work. The disadvantages of a central supply are the expense of the main cables, which are also liable to be cut in a bombardment, and the chance of the main power station being put out of action. On the whole it would appear to be better for each work to have its own installation for power and light, a supply of portable accumulator lamps and candles being kept for use in emergency. A description of suitable generating sets, together with typical lay-outs and designs, is contained in Military Engineering, Vol. VII.

40. Redoubts

(Plate 15)

1. *Main requirements.*—The same general principles apply to the tactical siting and design of a redoubt, as already described for a defended post. That is to say, the fire will be mainly flanking and delivered from casemates well protected against frontal fire. A redoubt will be capable of all-round defence and will contain all the necessary elements for protracted resistance. Its role will be that of a stronghold or centre of resistance in the main position (*see* Sec. **17**, 3), where it will be one of the links in a chain system of defence works, or it may be built to serve as a barrier fort at a strategically important point, such as a mountain pass or river crossing. The main armament will consist of machine guns, with some

anti-tank and anti-aircraft equipments, assisted by light machine guns and mortars for close defence. In the larger works the fire power will be further strengthened by the installation of light artillery of a semi-automatic nature, mounted either in cupolas or steel fronted casemates. Searchlights for illuminating the foreground are a necessary adjunct, while others will be required for anti-aircraft defence at night.

2. *Factors affecting design.*—

i. *General.*—The form of construction of a redoubt is largely a matter of site and terrain. Some may be built almost entirely underground on the lines of the new Hackenberg Redoubt near Metz, which is a marvel of subterranean technique, with its complete system of tunnels installed inside the hill, while it may be necessary to build others on the surface, in massive concrete, as in the case of the Hochwald " ensemble " in the Vosges. In neither case can it be expected that immense works of this nature can be so disguised and camouflaged as to escape bombardment, but the material protection afforded in the one case by masses of earth and rock, and in the other by solid reinforced concrete construction, should ensure a large measure of immunity against disintegration by the heaviest types of artillery or air projectiles.

ii. *Area.*—Redoubts will vary much in size according to the tactical importance of the site and the special role which the particular work has to fulfil. In general terms, it may be said that the determining factor will be the armament considered necessary for the defence requirements of the locality. Or, in other words, a work must be of sufficient dimensions to house the desired number of weapons and accessories, together with the appropriate garrison with its reserves and with the necessary accommodation for personnel and stores. Economy will be effected by the close grouping of the various defence elements, each of which will co-operate structurally in the protection of its neighbour. Thus one heavily concreted casemate will afford considerable protection to a similar element built in juxtaposition at its rear, while both will give safety to a dug-out underneath. On the other hand, it is probable that a direct hit on one element will in some degree be communicated to and affect its neighbour. It would seem, therefore, that some degree of dispersion is preferable, which entails more concrete if the whole structure is to be built in solid, or, alternatively, if earth gaps are left, these latter may be cratered in time, leaving bare the walls of casemates or roofs of galleries. It is a choice between two alternatives, the solution to which must be found in working out the best compromise possible for producing a compact work with

adequate protection for weapons and men at a justifiable expenditure of money.

iii. *Shape.*—Inasmuch as the size of a redoubt will depend largely on the number and nature of the weapons to be installed, so the shape will be governed by their location and grouping. In other words, the lay-out of the armament is the deciding factor, and this again has to be studied in relation to the ground and the position of adjoining works of defence. The plan of a redoubt, thus conceived, will consequently be of irregular shape, fitting into the natural feature of the ground, and allowing for the best possible field of fire of its armament. The normal shape will be somewhat oval or oblong in plan, with its axis or long side parallel to the front, or it may take the form of a flat triangle with its apex at the gorge or rear. The typical example shown in Plate **15** is of a small redoubt of the triangular pattern, which is a convenient shape for combining the advantages of a concrete massive for frontal protection, while the main armament is echeloned to the rear under its protection.

3. *Details of Construction* (Plate **15**).—

i. *The concrete massive.*—This is a heavy mass of concrete extending along the front of the work and overlapping each flank, thus affording efficient protection to the casemates echeloned behind it and acting as a guard to the entire work against direct or oblique fire. It also constitutes a solid counter-measure against projectiles fitted with delay-action fuzes, intended to attack and destroy the work from below. The massive may be put in solid or constructed on the composite principle described in Sec. **36**, 3, i, though the latter may present certain structural difficulties in the case of a work of irregular design or with varying levels.

ii. *Casemates.*—These are constructed on the principles described in Sec. **37**, 1. They are intended solely for fire, observation and the projection of light to the flanks. In the design shown there are four machine guns and a searchlight projector on each flank. The casemates are arranged in echelon, so that the projecting check of each will afford protection from frontal or oblique fire to that adjoining it, while all receive general cover from the main roof of the redoubt and the massive.

iii. *Cupolas.*—These are installed for weapons using direct fire and are intended for all-round defence. In the design shown the armament so installed consists of three machine guns, one at each apex of the triangle, two pairs of 3-inch semi-automatic guns, placed in a central position in the work, and a mortar operating from a shaft placed near the apex or

rear. A suitable type of machine gun cupola, made by Messrs. Vickers-Armstrong, is shown on Plate **10.** It is oval in plan, protected by a thickness of 10-inch armour plate in front and built in solid into the work. It is fitted with an observation slit on each side of the gun and an air vent. Protective padding is provided to reduce concussion from a direct hit. The 3-inch S.A. guns are housed in pairs in a disappearing cupola (Vickers-Armstrong) (*see* Plate **10**, Fig. 2). The cupola is circular in plan and is protected by a 14·8-inch armour plate. It is fitted with two air vent pipes and has a power-operated ammunition hoist. The remarks in Sec. **38,** 2, regarding measures for carrying off noxious fumes caused by firing machine guns apply equally here.

iv. *Combat gallery.*—This consists of a main gallery leading from the protected entrance in rear of the work to the forward observation post, with branch galleries to the casemates on each flank. The cupolas are reached by shafts rising out of the combat gallery. The protected entrance may consist of a loop-holed steel door on the surface, as shown in the design, or entrance may be by way of a tunnel leading to the rear and forming part of the subway system of the defences. The dimensions of the combat gallery should be of ample size to allow of free movement of men and ammunition, and a minimum of 6 feet 4 inches by 3 feet 9 inches is essential, with double-width passing places. Provision must be made for the storage of ammunition for the immediate needs of the weapons installed. If space allows, this will take the form of expense magazines led off the combat gallery, but in any case ammunition recesses must be provided in gun emplacements and casemates.

v. *Command and observation posts.*—The command post will usually be placed in a forward position, where a good view of the front can be obtained. In a small work the command post and forward observation post may be combined. Further facilities for observation will be provided by a rear look-out post, placed as in the sketch above the steel gate closing the entrance to the combat gallery, and by the provision of small diameter shafts driven through the roof at various points for periscope observation. Various types of command and observation posts are shown in Plates **5** to **8.**

vi. *Intermediate level.*—This level is protected by the main mass of concrete forming the roof, by the casemates and works under the latter and by the thickness of earth and concrete between the floor of the combat gallery and itself. It provides a safe position for combat dug-outs, with easy access to the machine gun casemates and cupolas. Magazines will also be constructed on this level, with facilities for rapid supply to

the gun floors above. Stores of all kinds and installation not affected by noise and vibration will be located here. Under this category may be included ration stores, shifting lobbies for gas-infected clothing, clean-clothing stores, engineer workshops, ablution room and latrines.

vii. *Deep level.*—This area is comparatively free from noise and percussion, where troops can obtain proper rest and sleep. Barracks and officers' quarters should be located here, together with such installations as are affected by percussion and earthquake, *e.g.* reserve water-tanks, machinery and power-plant. Plate **14** gives a typical lay-out for the barrack accommodation for a small defence work.

viii. *Anti-gas measures.*—In a closed work of the type described, where power is available, it should be possible to arrange for a constant supply of fresh or decontaminated air with a positive pressure to oppose the entry of noxious gas. All openings, *e.g.* loop-holes, ventilators, etc., should have efficient gas-tight shutters or tampions. Adits should be provided with pairs of gas curtains, and curtains should be fitted to all entrances to casemates, machine gun emplacements, etc. Shifting lobbies will be provided for changing gas-infected clothing, fitted with adequate cupboards for the storage of clean clothing and receptacles for the collection of gas-infected articles. A shower bath, supplied with hot water, should be available in case mustard gas has penetrated the clothing and reached the skin. Standpipes should be installed at convenient points for hosing out all the below-ground accommodation, including magazines, barrack rooms, stores and all passages.

ix. *Arrangements for counter-mining.*—Attack by mining is a slow but sure way to capture or destroy a work of defence when the more rapid methods of direct assault have proved unavailing. When, therefore, a redoubt is of sufficient importance, especially if it occupies a key position or is in an exposed locality, such as a salient, defence against underground attack must be provided. Such defence will take the form of a protective system, the primary object of which is to give warning of underground attack. Further, this protective system must be capable of development into a fighting system, should mine fighting develop.

Plate **16** gives a diagrammatic plan of an arrangement of this kind. It consists of a series of mined listening posts, so disposed along the front as to give warning of attack. The depth of these posts and their distance apart will depend on the depth of the mineable section of the ground and its listening properties. But the intervals must be such that it will not be possible for an enemy gallery to be driven between two posts without being heard from one of them.

The listening posts are mined off a lateral gallery, which is connected by two or more adits to the intermediate level system within the redoubt. The lateral gallery provides communication between the listening posts and enables concentration at any threatened point if mine fighting starts. It is in addition a great assistance to satisfactory ventilation. The lateral gallery and adits leading into the redoubt would be part of the permanent peace work, while the listening posts and the galleries leading to them from the lateral would be constructed when required.

For further details of defensive mining, *see* Military Engineering, Vol. IV (Demolition and Mining), 1934, Sec. 89.

x. *Water supply.*—An adequate supply of water is essential, with a good reserve, in case of the work being cut off or surrounded. The most satisfactory source of supply is a well, since this cannot be interfered with from outside, but, if this is not available water should be piped from an outside source. In the latter case the pipe line will be laid in a subway, if this exists, or buried to such a depth as to make it shell-proof. Reserve tanks to hold a specified number of days supply for the garrison must be installed. The pipe system inside the work should be arranged in blocks, controlled by valves, which can be closed in the event of a leak or break occurring in any section.

xi. *Power.*—A self-contained source of power supply is desirable, since it eliminates the danger of failure through the cutting of power cables or the wrecking of a central power station. A prime-mover and plant will be required for the following purposes and the peak load must be worked out accordingly :—

(*a*) The lighting of all the lower level accommodation, together with the galleries, etc., in the combat level, where daylight is insufficient or where light may be required at night.

(*b*) Power for the operation of cupolas, lifts, ammunition hoists, etc.

(*c*) Power for searchlight installations.

(*d*) Current for cooking and heating water for ablution purposes.

(*e*) Power for driving fans and extractors for ventilating and pure air supply (positive pressure).

A description of the plant and equipment required to carry out the services mentioned and of the most suitable and up-to-date pattern does not fall within the scope of this volume, and reference should be made to the appropriate volume of Military Engineering which deals with power installations and plant, and to the catalogues of firms which

supply special electrical equipment, such as electric ovens, water-heating apparatus, etc.

xii. *Lighting, ventilation, sanitation and comfort.*—These subjects have been dealt with in Sec. **39** in connection with defended posts. In a larger work of defence the same principles obtain, but their application may be varied to suit the somewhat different conditions, *e.g.* the larger size and more solid construction of a redoubt and the probability of a more permanent occupation by troops.

xiii. *Direction boards.*—At all communication gallery junctions there should be direction boards showing clearly all the places to which they lead. Every chamber, whether for fighting or other services, should have its purpose painted on its door or entrance, and, if for sleeping accommodation, the number of men for which it is designed should be stated.

41. Works for artillery

1. *Gun emplacements.*—In the construction of all gun positions concealment is of vital importance. Thus a well-sited and skilfully camouflaged gun or battery may remain in action for a very long time without being seriously interfered with, although the material protection to the gun may only be that of its shield or of a light splinter-proof roof. On the other hand, where shell-proof protection is necessary, a concrete emplacement of the type shown on Plate **17** can be constructed without being unduly conspicuous from the ground or air. The completed work, consisting of the gun emplacement, expense magazine and dug-out for the detachment, will take the form of a flat mound or barrow. The deep shadow in the recess of the embrasure must be toned down by the use of a fish-net screen while the gun is in action, and at other times by a tarpaulin painted to resemble the surface of the ground and stretched so as to carry on the exact contour of the mound across the openings. Other precautions against observation are the avoidance or careful concealment of tracks leading to the emplacement, the irregular spacing of emplacements if more than one is built, and the covering up of blast marks after firing.

The ruling dimensions of gun emplacements vary for the different types of guns and howitzers and are modified according to the arc of traverse required. Various designs, with certain modifications, are given in Plate **18.**

Splinter-proof cover for these is dealt with in the Manual of Field Engineering.

2. *Platforms.*—It has been explained in Sec. **18,** 3, that no platforms will be constructed in advance for field or medium artillery.

For heavy guns and howitzers, however, platforms will be prepared beforehand in the positions decided on. These should be as simple in design as possible and will be of two types, viz. :—

i. For pieces which are fired from their own travelling carriages.

ii. For pieces which are removed from their travelling carriages and fired from fixed mountings.

In the former case many equipments carry their own platforms and all that is necessary is the preparation of a bed for the platform.

3. *Railway mountings.*—A system of railway lines laid down for the use of guns on railway mountings will afford protection to the guns by giving them mobility and will add to their value for surprise effects.

Spurs will be required for the actual gun positions, and careful concealment and camouflage are necessary where these branch off from the main line.

Where possible, these spurs should be led through a wood or plantation, where effective concealment can be obtained. The method adopted in the Great War was to make a number of sockets along the line, in which small trees could be inserted, and to lace branches or tree tops across from one side to the other.

The gun position itself will require certain preparation, which will usually include a mass of concrete under the rails and extending outwards on each side of the permanent way, to support the outriggers for the gun truck. The construction of a command post for the gun position officer, dug-out accommodation for the detachment and a magazine are essential, and all must be very well concealed from air observation.

In cases where the gun does not fire from its travelling truck and is set up on a special mounting, a concrete pit must be constructed for the latter. It will also be necessary to lay additional lines on each side of the main spur to take the gantry crane, which is required for erecting the mounting and for setting up and dismantling the gun. An arrangement of this kind is shown in Plate **19**. This particular gun was one of those used by the Germans in the bombardment of Paris in the spring of 1918. It was a 9·13 inch gun weighing 154 tons, with a range of about 80 miles. It is said to have been dismantled for reboring and a new gun brought up and mounted in its place in three days.

4. *Observation posts.*—

i. *Concealment and protection.*—These will depend for protection rather on concealment than on material, as, when

once located by the enemy, a post can be quickly put out of action by smoke clouds. Invisibility of the observer is the primary consideration and every observation post must conform to the nature of the ground on which it is located. An important point to be remembered is that access to the post must be concealed as much as the post itself. In most cases only splinter-proof cover can be hoped for, without sacrificing concealment, but reinforced concrete observation posts can often be effectually concealed by being built inside existing buildings. It is not easy to hide deep protected loop-holes in a forward position, when a large field of fire is required, owing to the heavy shadow thrown by them. Wire gauze stretched over the loop-hole assists greatly in disguising it and field glasses can be used behind it. Loop-hole plates are of value for observation posts close to the enemy's line, as they afford protection and conceal the shadow of the embrasure (Plate **5**, Fig. 3).

Observation may be either direct or by means of a periscope, but the latter is not so satisfactory as direct view and would only be employed when the observation is far forward.

ii. *Accommodation.*—Artillery observation posts require accommodation for the observing officer with a table for his maps, etc., facilities for using a telescope without the instrument projecting beyond the observation slit, and a room for two telephonists, who must be within easy speaking distance of the officer. This room may in some cases be placed immediately below the officer's position and take the form of a protected dug-out, as shown in Plate **6**.

iii. *Construction details.*—The observation slit should be of irregular shape, and not less than 6 inches deep. Head-room above the slit should be not less than 6 inches. The slit should be 5 feet 6 inches from floor level to enable a tall man to use it ; a platform can easily be placed for a short man.

The slit will be about 3 feet long or according to the field of fire required.

The floor area must be as small as possible in order to reduce wall and facilitate concealment. About 36 square feet is the minimum area for work and comfort.

A shelf should be provided under the slit for the observer's field glasses, etc., and for his elbows to rest on.

The observation post should be made gas-proof, for which purpose the observation slit may be provided with a non-splinter glass loop-hole.

iv. *Special forms of observation posts.*—A portable steel tower is shown in Plate **7** and an observation tree in Plate **8**. The former is chiefly useful in a rear position where it can be

concealed among tall trees, while the latter is an expedient for establishing an observation post in the shelled area close up to the enemy's lines. Accurate measurements and a sketch of a particular tree are taken, which is then reproduced in exact detail at the camouflage workshop in rear. The tree is then sawn down under cover of darkness and the camouflage observation tree erected in its place.

5. *Chambers for flash-spotting and sound-ranging.*—

i. The tactical siting of flash-spotting and sound-ranging posts is dealt with in the Manual of Flash-Spotting and the Manual of Sound-Ranging, respectively. Their positions must be accurately fixed.

ii. Flash-spotting posts are normally manned by two men, an observer and a telephonist ; in exceptional circumstances both men may have to observe, though normally one man observes and the other records the observations, transmitting them, when necessary, to headquarters.

The slit should be not less than five feet wide to allow two instruments to be mounted. It should be at least six inches deep on the inside and its outer dimensions should be sufficient to enable the instrument to be elevated or depressed enough to cover all the ground to be observed.

If the posts are dug in, the slit should be sufficiently above ground to clear any long grass, wire entanglements, etc., immediately in front of the post.

The minimum size of the flash-spotting posts may be taken as 5 feet by 6 feet for ground stations.

In flat country it may be necessary to erect observation towers (*see* Plate 7) or to place posts in chimneys or church spires. In such cases it may be necessary to reduce these dimensions and to arrange for the telephonist to work in a compartment below instead of beside the observer.

The post should be provided with a rigid shelf for the instrument, six inches below the inner edge of the slit, a stool or bench for the occupants, who should be able to sit down while at work, a small table about 2 feet by 2 feet for the telephone, and a sloping desk at the side of the post, on which maps, paper, etc., can be spread out, and which should be placed beside the observer so that he can conveniently consult the map while at work.

Concealment of the post is of more importance than bomb-proof protection. Shell-proof overhead cover cannot, therefore, always be provided. Protection from weather and from shrapnel, splinters, etc., should, however, always be provided and the slit should be protected by a hinged flap when not in use. This flap may with advantage be provided with glass windows.

When bomb-proof cover to the post itself is not possible, protection for the occupants should be given by means of a concrete or mined dug-out alongside the post and in direct communication with it.

iii. Accommodation is required for the following in a flash-spotting headquarters :—

Three plotting boards, each about $3\frac{1}{2}$ feet square.
Table for ranging plotter.
Table for telephonist.
Telephone exchange.
Maps, records and books.

About 150 square feet may be taken as the minimum area necessary.

In addition to the above, separate compartments or rooms are required for :—

Administrative office, about 80 square feet.
Store, about 100 square feet.
Wireless operator, about 40 square feet.

Appropriate furniture should be provided in each of these compartments.

A good light is desirable, but it is not essential, as the greater part of the activity of a flash-spotting group takes place at night.

iv. *Sound-ranging posts.*—The advanced post is normally manned by three men, all of whom, however, are not actually on duty at the same time.

A circular post with an all-round view is most convenient. The diameter should be about six feet, which is sufficient to enable the observer to move round a central pedestal or table on which a map is mounted.

The principal part of the observer's equipment is a map suitably mounted, so that the direction of any shell-burst can be quickly obtained by laying on it with a pivoted alidad.

Protection should be given from weather and sufficient cover to guard against shrapnel and splinters. Bomb-proof cover should be given by means of a mined or concrete dug-out alongside the actual post.

v. The accommodation required at headquarters consists of :—

Instrument room, minimum size about 150 square feet.

Computing and plotting room, minimum size about 150 square feet.

Room for accumulators, minimum size about 50 square feet.

Place for charging accumulators, with sufficient ventilation, minimum size about 50 square feet.

Store, minimum size about 100 square feet.
Workshop, minimum size about 100 square feet.
Administrative office, minimum size about 80 square feet.

The instrument at present used records photographically and has an automatic developer.

The charging set and accumulator bank should be placed close together, the charging set being furthest away from the computing room.

The sound-ranging instrument is usually mounted on a strong and rigid table, about 7 feet by 3 feet 6 inches, and placed sufficiently far from the walls to enable the sound-ranging operator to walk all round it.

Another table or shelf is required in the instrument room for telephones.

The computing room should be provided with a long bench or table down one side of the room and under the window or light.

It is desirable that there should be room for the computing officer and four men to sit and work side by side at this table. The computing officer requires at least five feet of lateral space and the four men three feet each.

In addition tables for two plotting boards, each 36 inches by 42 inches, are required, a small table for a telephonist and a telephone exchange, and shelves for maps and papers.

vi. *Co-operation between sound-ranging and flash-spotting.*—To assist in the co-operation between flash-spotting and sound-ranging sections, it is desirable that the respective headquarters responsible for the same counter-battery areas should be close together and, if possible, in the same building.

42. Headquarters and command posts

1. *Requirements.*—Headquarters, including signal offices, will be required for brigades and divisions. In the case of a brigade, in places where deep dug-outs can be constructed, headquarters may be accommodated in a lay-out of the type shown in Plate **3**.

2. For a divisional headquarters it is usually more convenient to provide separate accommodation for the two branches of the staff, and a dug-out of the type shown in Plate **3** will be required for each.

3. Permanent dug-outs, together with their galleries and entrances, must be lined with brick, concrete or steel sections bolted together. If brick is used, the exposed face should be of white glazed finish, which can be kept bright and clean and

decontaminated by hosing down. For the same reason the surface of the concrete should be smooth finished and washed over with a solution of sodium silicate. The best type of steel sections are those made of rustless steel. All paints, varnish, oil and grease absorb persistent gas, such as blister gas, and their use should be avoided. The above and all other important headquarters should have adequate gas protection, as mentioned in Sec. **39, 9**.

4. *Concrete cellars.*—Where the ground is not suitable for deep dug-outs, divisional headquarters may be located in concrete cellars under existing or specially constructed buildings. A suitable type is shown in Plate **4.**

5. Divisional artillery and engineer headquarters should normally be distinct from divisional headquarters, but sited near the latter. Accommodation as shown for a battalion headquarters (Plate **2**) is of suitable type.

6. *Command posts.*—Battalion headquarters are normally placed in one of the redoubts or larger defence works, while company headquarters are provided in defended posts, being incorporated in the general design of such works.

Battery command posts, and in certain cases those for machine gun and anti-aircraft headquarters, are provided separately, and these should be in deep dug-outs, wherever the ground admits of their construction.

7. *Design and accommodation.*—Space must be given for the full complement of personnel required for efficient working. The labour required to construct a chamber is small compared with that required for the entrances and galleries, and the saving effected by providing insufficient chambers is not worth the sacrifice of efficiency.

8. *Types.*—Plate **2** shows a suitable lay-out for a battalion headquarters.

Plate **1,** Fig. 2, gives the accommodation required for a company headquarters or a machine gun command post, to which a wireless chamber must be added for a battery command post. The battery command post should be about 60 yards away from the battery in rear and to a flank of it.

9. *Concrete structures.*—In cases where underground protection cannot be provided, resort must be had to reinforced concrete structures, which may be placed within existing buildings, where such are available.

10. All command posts and headquarters should be provided with electric light, with a reserve of portable accumulator lamps for use in case of the current failing.

43. Observation and intelligence posts

1. The installation and maintenance under fire of good observation posts is one of the essentials of a defensive organization. Since fortification to a great extent immobilizes troops, it is all the more necessary to watch every movement of the enemy, so as to be able to frustrate his initiative.

2. Infantry look-out posts may be constructed on the same lines as artillery observation posts (*see* Sec. **41,** 4), but when concealment is difficult, accommodation may be provided only for the observer and his telephone. A simple form of cupola observation post is shown in Plate **5,** Fig. 2. This can be used for direct view through the loop-hole in front, and observation made by means of a periscope or stereo-telescope through the opening in the dome of the cupola. For other types of observation posts, *see* Plates **6** to **8.**

3. Intelligence posts are special observation posts for the purpose of keeping a continual watch on the enemy lines with the idea of noting any sign of movement, activity or change. A site should be chosen which commands as extensive a view as possible into the country occupied, so that roads, occupied buildings, railway lines, battery positions, etc., come within the range of vision. For this purpose an elevated site is naturally best, and one not occupied by works of defence or near a battery position. In a quiet position such as this it will be possible to maintain a constant watch without attracting the attention of the enemy, provided that the cell is well concealed and camouflaged, there is no movement in its vicinity during the hours of daylight and no well-marked path or approach to it which would show up in an air photograph. The observation chamber should be fitted with a shelf on which the telescope stand can rest and with room for a chart. Since the usual routine is for the observer and his relief to spend the whole day in the post, some provision should be made for a bench or bunk for the man not on duty.

44. Shell-proof cover for troops

1. The protection of the personnel actually engaged in fighting and of their weapons is provided in concrete machine gun posts, casemates, cupolas, etc., while their reliefs are accommodated in combat dug-outs or shelters, close at hand and with easy access to fighting posts. In addition to the above, shell-proof cover is required for all other troops in the line, to give security during bombardment and as living accommodation. Further it is essential to make provision for similar protection, in some degree, for rest billets, depots and establishments behind the line, which are liable to long-range bombardment or air raids.

2. *Surface construction.*—Shell-proof cover on or just below ground level in the form of reinforced concrete structures will be provided for the combat shelters referred to above, for observation posts, look-out posts, etc., where a view is necessary, and in cases when the ground is definitely unsuitable for tunnelling for the accommodation of small detachments in rest or reserve.

The *advantages* of this type of construction are :—

i. Easy access to fighting posts.
ii. No difficulty about ventilation, lighting and drainage.
iii. They can be built in the best tactical position irrespective of the nature of the ground.

The *main disadvantages* are :—

iv. Difficulty of concealment.
v. No immunity from noise and concussion.
vi. Size limited for constructional reasons.

3. *Deep-level construction.*—This is the normal method of providing shell-proof cover for troops not actually engaged during a bombardment, and for living accommodation in the forward defences. Where a system of tunnelled subways has been constructed to connect up the various defence works and posts (*see* Sec. **42**), deep dug-outs will be located in the works themselves or at convenient positions along the subways. In localities where no subways exist, *e.g.* in battery positions, at railheads and generally in the back area, detached dug-outs will be constructed of suitable size and provided with independent exits to the surface.

The *advantages* of deep dug-outs are :—

i. Their construction involves less labour compared with surface shelters in proportion to the accommodation given.
ii. They give complete protection both from actual penetration and concussion effect.
iii. Their existence and position are concealed.
iv. Additional accommodation can be added at any time.

Their *main disadvantages* are :—

v. Time taken to reach fighting posts in case of alarm.
vi. Technical difficulties of ventilation, lighting and drainage.

4. *Shell-proof depth.*—The minimum depth of earth required in the case of different strata is as follows :—

Made earth	35 feet.
Clay	30 ,,
Gravel	25 ,,
Chalk	20 to 25 feet.
Hard rock	15 feet.

It is an advantage to reach hard chalk, even if it involves deeper sinking, as the work of shoring up and lining galleries and chambers is thereby reduced. In the case of accommodation provided as part of a defence work (*see* Secs. **37** and **38**), a considerable amount of protection is afforded by the concrete structures above, so that the depths of earth cover overlying the deeper levels may be proportionately less.

5. *Classification of deep level accommodation.*—The normal requirements in deep level construction may be classified as follows :—

i. Living accommodation provided as part of a defence work for occupation by the garrison and its reserve.
ii. Dug-outs for batteries, machine-guns group, and troops holding sectors of fire trench.
iii. Accommodation for special counter-attack troops.
iv. Command headquarters for higher formations and for those not provided in (i) and (ii).
v. Dressing stations.
vi. Dug-outs for protection against occasional long range shelling and bombing at railheads, rest billets, advanced store depots, etc.
vii. Bomb refuges in the back area.

6. *Design :*—

i. Plate **14** gives a typical design of shell-proof living accommodation built within a defence work. It contains all the essentials for a long occupation, including provision for cooking, washing and sanitary arrangements. Details are given in Sec. **39**, 12.
ii. There are two general types, which allow of variation in the size, number and arrangement of chambers and from which suitable accommodation can be planned for categories (ii), (iii), (vi) and (vii) in para. 5, above, viz. :—

   Type A (Manual of Field Engineering, Vol. II, 1936, Plate 48, Fig. 1), which is suitable for offices and officers' quarters.

   Type B (Manual of Field Engineering, Vol. II, 1936, Plate 48, Fig. 2), which is suitable for men's quarters. This type involves less excavation for the accommodation provided and gives better ventilation.
iii. A suitable type for command headquarters is given in Plate **3**.
iv. Details of a dressing station are shown in the Manual of Field Engineering, Vol. II, 1936, Plate 47.

7. *Constructional details* :—

i. *Dimensions*.—It is desirable in designing the chambers to keep to a fixed width, in order that the length and section of R.S.J. used may be standardized. A joist about 9 feet in length and 5 inches by 3 inches in section is the most suitable size. A span of 9 feet (giving a width of 8 feet in the clear) provides adequate room for bunking accommodation and is a satisfactory and economical dimension for all purposes. The corresponding height to the ceiling is 6 feet 6 inches in the clear.

A good method of bunking is shown in Plates **2** and **3**. It provides a seat and a blank wall for hanging kit. Bunks should be 6 feet 2 inches by 2 feet. The cubic air space allows for three tiers of bunks, but it is better to arrange for two tiers with a space of 1 foot 6 inches under the lower bunk to facilitate sweeping out.

Chambers or rooms of considerably larger dimensions may be required for special purposes in permanent construction, such as the living quarters of a defence work, and girders of large section will be required to support the roofs. Such provision should, however, be kept to a minimum, in view of the cost and the difficulty in handling long and heavy girders in inclines and passages.

ii. *Material*.—The normal method of underground construction with pit props and R.S.Js., or entirely in timber, is described fully in Military Engineering, Vol. IV, 1933, Chapter XI, and the Manual of Field Engineering, Vol. II, 1936, Chapter V. This method is of general application to all works of a semi-permanent nature, *e.g.* for dug-outs in battery positions and for use as bomb refuges, etc. In permanent work it is desirable to eliminate timber as far as possible, chiefly on account of the absorption of persistent gas in woodwork and the danger of fire, which is much enhanced by the normal installation of artificial air pressure. All timber work will therefore be replaced by R.S.Js. resting on steel frames or stanchions, and the top and side lagging will consist of interlocking steel troughing, preferably made of rustless steel. As an alternative, the walls of chambers may be lined with glazed brick or by means of concrete panels on expanding metal sheets. Floors will be of concrete laid to a slight fall to a channel either in the centre or along one side of the chamber, connecting with one of the sumps in the drainage system.

8. *Preparation of schemes*.—A careful reconnaissance is essential before any tunnelling work is begun. The whole question of deep level accommodation should be taken up as part of the defence scheme referred to in Sec. **35,** and a

geological map prepared showing the localities favourable for tunnelling or otherwise and the lines proposed for subways and sites of dug-outs.

In addition a site plan and working drawings will be required for every separate job. (*See* Military Engineering, Vol. IV, 1934, Sec. 82, 5.)

45. Tank obstacles and mines

1. *Open spaces.*—Existing tanks are capable of crossing trenches approximately as wide as one-third of their own length, of demolishing walls 2 feet thick and of crossing rivers having little current and with banks offering good landing. Improvement in tank design is likely to be rapid, so that any effective artificial obstacle in the open would require an immense amount of labour to construct, would be known to the enemy and would therefore be of little value.

Thick woods or shallow inundations over soft soil, which, when wet, will not offer a grip to the tank tracks, may be effective as obstacles, but, for defensive protection, mines and light anti-tank guns in concealed positions must be provided.

The detonation of 15 lb. of ammonal or gun-cotton, buried not more than one foot below ground level, will effectively disable a tank passing over it.

A vertical bank, five feet high, cut in rock or revetted with brick or stone and flanked by anti-tank guns, forms an effective obstacle, but, owing to the time and labour involved, a continuous obstacle of this nature would seldom be practicable. Short lengths can, however, be placed to shepherd attacking tanks into mined areas or within the effective range of concealed guns.

2. *Confined spaces.*—In defiles or in the by-streets of towns and villages it is possible to hinder and delay the passage of tanks by the erection of obstacles. Three types of such obstacles are shown on Plate **20.**

Figs. 2 and 3 show an obstacle formed by blocks of concrete, which act as anchorages to bars of iron set at an angle and pointed. These blocks are so placed as to catch the tracks of a tank. Fig. 1 shows the plan and also the spacing required, but this spacing will, of course, depend on the track of the enemy tank likely to be encountered.

Figs. 4 and 5 show another form of obstacle, placed in a similar manner to that shown in Figs. 2 and 3, but in this case the tank rises at one side owing to one of the blocks getting under its belly, and thus the forward movement of the tank is stopped.

Fig. 6 shows a concrete wall 6 feet high with projecting iron bars to stop tanks.

3. *Types of mines.*—Mines are generally of the automatic type, either mechanically or electrically controlled, and can be set at *live* or *safe* as required.

Existing tanks exert little more pressure to the square inch on flat ground than an infantry soldier, but the firing mechanism of a contact mine can be made to project slightly above ground level and to take a large portion of the weight of the tank. In this way it is possible to make a contact mine safe for infantry but effective for a tank. Various types are at present under consideration and certain details of designs, with the method of laying and firing arrangements, are given in Military Engineering, Vol. IV, 1934, Secs. 64 and 65.

46. Signals works services

Signals works services comprise the construction of protected accommodation for signal offices, signal centres, test points and wireless or visual terminals which are not inside the signal office. The construction of buried cable routes is a signals responsibility, but co-operation between the engineer and signals authorities will be necessary if it is required to run the cables in tunnels or sub-ways, or if engineer and signal cables are to be run in the same trench.

The degree of protection for a signal office or signal centre will be not less than that of the headquarters which it serves.

The accommodation required includes space for instruments and signal office personnel, including a table for signal office clerical duties. The following tables give the necessary scale.

TABLE A.—ACCOMMODATION REQUIRED FOR SIGNAL OFFICES AND THEIR PERSONNEL ON A DIVISIONAL FRONT

Description of headquarters	Shell-proof dug-outs for—	
	Signal office area	Personnel (additional accommodation)
(1)	(2)	(3)
	Feet	No.
Division	18×9	50
Brigade	10×9	24
Artillery brigade ...	10×9	20
Battery	10×9	12
Battalion	10×9	12

TABLE B.—ACCOMMODATION REQUIRED FOR WIRELESS SETS AND THEIR PERSONNEL ON A DIVISIONAL FRONT

This is still a matter of experiment. The information will be published in an addendum to this manual.

47. Aerodromes and aircraft landing grounds

1. The work required for the Royal Air Force component in a theatre of war is dealt with in full detail in Military Engineering, Vol. VII, 1934, Chapter XXXVI.

It will be sufficient, therefore, for the purposes of this manual to summarize the special requirements of air formations in a fortified region with a view to the reservation of suitable sites and the execution of certain essential work in peace.

2. Landing grounds will, as a rule, be sited at a considerable distance from the front line, but those required for army co-operation squadrons should be located as near to divisional headquarters as possible. Every effort should be made to select sites in positions difficult to locate from the air, especially with regard to conspicuous features which can be readily identified from the air, such as railway junctions, road intersections, rivers or other water surfaces, etc.

3. The main considerations in the selection of a suitable landing ground are :—

i. Dimensions and shape.
ii. Surface, slope and drainage.
iii. Air approaches and general surroundings.
iv. Communications ; water supply and camping facilities.

4. i. The normal minimum dimensions of a landing ground are 500 yards in any direction. The best shape is a square or rectangle or, failing these, an L or T shaped ground may be chosen with arms 500 yards long and 250 yards wide. Irregular-shaped grounds are confusing and should be avoided.

ii. The surface should be free from furrows or ditches and from any sudden change in the degree of the hardness of the soil or in the slope of the ground. As a guide to the general smoothness and firmness of the ground, it should be possible to drive a car at 35 miles an hour over any part of it without inconvenience, or a 3-ton lorry fully loaded without the wheels sinking in.

iii. Trees and buildings in proximity of the ground are serious obstacles. The cutting of air gaps in belts of trees may be necessary. The vicinity of steep hills is dangerous. Telegraph wire should be buried or removed from the vicinity.

iv. Good road access is essential. An adequate water supply, and either camping or billeting facilities, are required.

5. The provision of accommodation on landing grounds will vary considerably according to circumstances. In

advanced landing places liable to air attack the main consideration is the concealment of the ground as much as possible. Aircraft will either be pegged out in the open at considerable distances to minimize damage from bombs, or hidden in neighbouring woods, etc. Traverses will be constructed to protect individual aeroplanes, forming a bay or stable in which the machine rests (*see* Military Engineering, Vol. VII, 1934, Plate 144). It is unlikely that buildings will be put up on forward landing grounds. Existing farmhouses, etc., in the vicinity will be adapted as stores and workshops and for the accommodation of the personnel. Bombs will be stacked as convenient and covered with tarpaulins, with traverses constructed round groups.

6. In more remote landing grounds, which are not so liable to air attack, it will be possible to provide tent or other hangars of transportable type for the aircraft, together with huts for offices, wireless cabin, workshops and stores, and hutted accommodation for officers and men. A degree of concentration will be advantageous in respect to economical and convenient administration, but the importance of keeping the air approaches clear must not be overlooked.

7. Ground defence will be a necessity in most cases in view of the raiding possibilities by troop-carrying aircraft. For this purpose the accommodation area will be surrounded by a barbed-wire apron fence with machine gun posts at the re-entrant corners.

48. Roads

1. As already pointed out in Sec. **28**, the road system in front of railhead is of immense importance in a fortified zone, since on this depends the expeditious and regular delivery of supplies and ammunition to the fighting troops and the means of lateral communication for mutual support. Roads constructed in the area behind a defensive position have to meet the most exacting demands of traffic. The use of mechanical transport, with the resulting increase in the weight of vehicles and loads carried at considerable speed, has added considerably to the road and road-bridge problem.

2. *Requirements for operations.*—Provision must be made to supplement or improve existing roads and tracks with respect to :—

i. Roads for the extra traffic entailed by the concentration of troops and their subsequent advance and maintenance.

ii. Forward roads in the defensive area.

3. *Roads for extra traffic.*—The deliberate work to be undertaken will include :—

i. Improvements to existing roads.
ii. New roads.
iii. New approach roads to additional railheads or improvements to those existing.
iv. By-pass roads to extra refilling points, water points, dumps, etc.
v. Entrances and exits to new camps, casualty clearing stations, railhead rest camps, etc.
vi. Maintenance dumps of material for road repair.

4. *Main roads.*—At least one good road should be made available either by new construction or by improvement of an existing road, as the main line of advance and supply for each division, but two roads, one for "up" and the other for "down" traffic are much to be preferred, where possible, with a view to meeting increased traffic before and during operations and to facilitate traffic control. All such roads should have a good metalled surface with a footpath on at least one side for pedestrian traffic. If only one road can be made available for each divisional sector, its width should be 50 feet to take three lines of traffic and include a footpath on each side. If the road is duplicated, a width of 30 feet to take a double line of traffic with one footpath will be sufficient. The best form of construction is tar macadam, as this will stand up to a lot of hard wear and is more easily maintained and repaired after damage by shell than reinforced concrete or *pavé* switch roads. In order to avoid heavily shelled cross-roads or villages, switch roads should be constructed. These should be double traffic roads 24 feet in width and preferably made of macadam, though timber slabbing is permissible where the traffic is not too intense.

5. *Approach and by-pass roads.*—The heavy traffic during concentration at rail-head, refilling points, dumps and water points renders it necessary to pay particular attention to approach and by-pass roads. Where there is heavy lorry traffic, metalled or stone-sett (*pavé*) surfaces are preferable, but, if these cannot be provided, sleepers should be used; beech slabbing, unless of extra thickness and very carefully laid, is not strong enough.

6. *Construction.*—The details of construction of all classes of roads are given in Military Engineering, Vol. V, 1935, as follows :—

Macadam, water-bound and tar-bound, Chapter V; corduroy and plank roads, Chapter XIII; paved roadways, Chapter VIII.

The masonry structure involved, which consists of bridges, culverts and retaining walls, is dealt with in Chapter XII.

7. *Forward roads.*—Existing roads and tracks will be largely used, supplemented by sections of new road, which may be part of the peace provision or constructed after the beginning of hostilities.

The chief objects of forward roads are :—

i. To ensure the supply of stores and ammunition to the troops in the line.
ii. To facilitate the movement of artillery.
iii. For the forward movement of reinforcements or counter-attack troops.
iv. For lateral communication and support.
v. For the evacuation of casualties.

Construction.—New roads constructed to meet the tactical needs of the defence position will be of macadam and either of double-way width or single-way with passing places. Existing roads will be improved by widening the easing of gradients and straightening bends; where general widening is impracticable, it will be necessary to provide passing places at reasonable intervals. Lanes and cross-country tracks can be made practicable for traffic by the use of heavy timber planking known as slabbing, to form a corduroy or plank road. This is often a satisfactory solution in soft or heavily shelled localities.

A typical example of a forward road system is shown on Plate **21**.

For detailed information on the construction and repair of forward roads, *see* Military Engineering, Vol. V, 1934, Sec. 36.

8. *Road screens.*—Screens are employed for the purpose of concealing roads, tracks and other important work from direct enemy observation. All roads and tracks on which there is much daylight traffic will require screening when they are under enemy observation, both as a precaution of safety and to conceal the extent of movement taking place. The result of experience shows that, if screening is carried out on a comprehensive scale and with a continuous policy, localities which, being under observation, would normally be subject to deliberate shelling become practically immune.

Siting of road screens.—Roads running at right angles to the front are best screened by hanging vertical screens across the road between trees or poles. Roads running more or less parallel to the front are screened by siting the screens at least 50 yards from the edge of the road, in order that shell fire directed on the screens shall not cause damage on the road. Short lengths of about 30 yards placed in echelon and

overlapping each other are preferable to long continuous screens. This method permits of plenty of passage ways and limits damage by shell fire. Further, the line of the roads so screened is not defined and is therefore difficult to range on. Plate 22 shows (i) method of screening a road from enfilade view and (ii) method of screening a road parallel to the front. Details of various types of screens, their manufacture and erection are given in the Manual of Field Engineering, Vol. II, 1936, Chapter VIII.

49. Rail communications

1. Railhead is the standard gauge rail terminus or point of transhipment of personnel and stores of all kinds. Distribution from railhead will be by means of lorries and other vehicles operated along roads leading to the front, supplemented in some cases by a light railway system. In general terms the nearer railheads are to the position occupied by the troops the shorter will be the length of roads to be maintained for the forward traffic, but on the other hand railheads in advanced positions are very vulnerable to long-range artillery fire. It is impracticable to operate a railhead of any size within effective range of medium artillery.

2. *Selection of a railhead.*—The general considerations for the selection of a railhead are laid down in Sec. 96, Field Service Regulations, Vol. I.

The following are special points affecting engineer questions :—

i. *Sidings.*—Sidings of sufficient length are necessary at which pack trains can be unloaded without interfering with main line traffic. A length of 210 yards will take a normal pack section for a division consisting of 21 10-ton trucks.

ii. *Station yards and approaches.*—Good approaches are essential and they should have separate roads for entrance and exit. The station yard should be of ample size with a level surface which should stand heavy traffic in all weathers, *i.e.* tar macadam on a good foundation or concrete.

iii. *Assembly positions and parking grounds.*—In order to minimize the risk of congestion in the station precincts, assembly positions for troops and parking grounds for lorries and motor vehicles should be provided in the vicinity of railheads. A reasonable amount of dispersion is permissible in the selection of sites for such purposes, and use should be made of woods and plantations for concealing them from air observation.

iv. *Water supply.*—An adequate supply of water is required for filling boilers and tenders, as well as for the personnel of railhead and for the troops passing through. An ample reserve should be available, which should be stored, if possible, in bomb-proof reservoirs or groups of cisterns.

3. *Accommodation.*—Accommodation will be required for railhead personnel and it will also be necessary to establish a railhead rest camp for troops arriving or leaving by train.

Suitable lay-outs and types of hutting for this purpose are described in Military Engineering, Vol. VII, 1934, Part II.

4. *Protection against enemy action.*—Enemy attacks may take the form of a long-range artillery fire or be made by means of low-flying aircraft with machine gun fire or by gas or H.E. bombs from high flyers. It is impracticable to afford material protection to station buildings and the permanent way, but the danger from H.E. bombs or shells can be localized in goods yards, groups of huts, etc., by the provision of splinter-proof traverses. A good system of deep dug-outs should be planned for the protection of troops and railhead personnel during a bombardment.

This should include large dug-outs adjacent to the troop platforms and others accessible to railway-operating and administrative personnel throughout the area comprising railheads. All dug-outs will be fitted with anti-gas protective measures.

5. *Station equipment, platforms, etc.*—These are fully described in Military Engineering, Vol. VIII, 1929, Chapter XVII, and Plate 10 gives a typical design for a railhead.

50. Tramways

1. *Uses and types.*—Tramways will be of the greatest assistance for the rapid execution of work on mobilization, for the transport of munitions and supplies into the forward zones during siege operations and for work on concrete posts.

These tramways may be described as the man—or animal—operated continuation of the light railway system and will consist of the 20-lb. 60-cm. track described in the Manual of Field Engineering, Vol. II, 1936, Chapter XXI.

Such tramways should lead to advanced dumps and not direct to defensive works, as if the latter were adopted the location of works would be apparent to the enemy.

Full details of all track routes and material, dumps and labour required in connection with them would form part of the defence scheme (Sec. **35**). Some of these tracks could be

laid in advance; those tracks which were not laid before a period of political tension would be laid on mobilization or during the precautionary period.

2. *Peace preparations.*—In order to reduce the work to be done on mobilization to a minimum, a certain amount may be done in peace by the preparation of the formation level at difficult points and by the erection of bridges, where required, but these preparations must not be on such a scale that they will show the location of lines in air photographs, and the true purpose of bridges must be disguised by erecting them in such positions that they appear to be those required for ordinary local traffic.

CHAPTER VI

SUPERINTENDENCE OF WORK—MACHINERY

51. Superintendence of work

1. *Policy and control.*—In order to obtain proper co-ordination of principles and methods, and to ensure continuity of policy, the superintendence of the design and the technical supervision of the work will be the responsibility of a senior engineer officer. To carry out this work, he will require an adequate staff, together with sufficient means of transport to ensure that close touch is maintained with the executive personnel. This superintending organization is necessary whatever may be the scheme of control of the construction of the defensive system, *i.e.* whether the army, corps, line of communication or a specially appointed commander under G.H.Q. is responsible for the work to be done.

2. The organization required is as follows: The trench system is divided into sectors, approximately six miles long, each under a C.R.E., who has under him a field engineer for every 1½ miles of the sector. A sector will usually coincide with that part of the system which lies within a corps area.

For the supervision of four sectors, or of that part of the system lying in the army area, a C.E. is required.

3. *Understudies.*—In order to ensure continuity of policy and of control, it is essential that C.Es. and C.R.Es. should have officers to understudy them. In the sector this officer will also normally be charged with the duties connected with stores. A C.E. will need, in addition to his understudy, an officer whose sole duty will be to arrange for the supply and distribution of stores required by the sectors.

Artillery and machine gun officers must be attached to the H.Q. of C.Es. for duties connected with the design and construction of artillery and machine gun defences. A signals officer should be called into consultation in planning signal offices and accommodation and signal centres.

4. *Staff, stores, etc.*—The senior engineer officer responsible for the superintendence of the system will require a staff, which will vary in composition according to what formation is responsible for the work, whether G.H.Q., army, or corps. The

provision of personnel for the performance of the duties connected with the following will have to be considered :—

i. Liaison with C.Es.
ii. Stores.
iii. Transportation.
iv. Records.

The first is essential to ensure efficient co-ordination of effort and the proper distribution of labour, both technical and non-technical, and of stores.

The importance of the stores duties will depend on the source from which the stores and materials are drawn.

The allotment of mechanical transport must be controlled by the senior engineer officer responsible for the system if the best results are to be obtained. Economy of labour, etc., may result from the construction of light railways and tramways up to the site of the defensive system.

The transport required by the superintending organization will vary according to the nature of the country and to the rate at which the work is to be done. The C.R.E. will require mechanical transport (7 or 12-cwt. van) for the movement of small arms, etc., and also horses for himself and for his understudy for the supervision of cross-country work. C.Es. and C.R.Es. will require motor-cars for supervision and liaison duties and lorry transport for the distribution of stores. A motor-bicycle despatch-rider service is essential in order that C.Es. and C.R.Es. may be kept continually well informed of the progress of the work and of the requirements of sectors.

52. Organization of labour

1. *Methods of obtaining labour*.—Unskilled labour for work on rear defence systems may be provided by labour companies, either white or coloured and specially enlisted for labour purposes, and by units and formations temporarily withdrawn from the fighting line. Similarly, the technical troops may be supplied by army troops and by other engineer units specially allotted.

Labour may, in some cases, be obtained in the form of civilians hired locally, in which event the men must be organized in gangs of about ten under a foreman or ganger.

2. *Task work*.—Work should, whenever possible, be given to all labour in the form of a task for each unit or gang, the amount of the task being settled by consultation between the C.R.E. or field engineer and the officer or foreman in charge of the labour.

53. Supply of material and stores

1. It is a general principle that the design of works must conform to the stores which are available. Such stores consist of :—

- i. Ordnance tools supplied from the base.
- ii. Engineer stores, including both constructional plant (*see* Sec. **56**) and material supplied from the base.
- iii. Material obtained locally (*e.g.* brushwood, concrete aggregate, etc.).

2. The general staff decide what stores can be supplied from the base in any given period.

3. The C.E. in charge of the execution of the work must arrange with the movements branch of the staff as to when the stores can be moved to railhead ; and with the Q.M.G.'s branch of the staff for sites for railhead parks and for road transport from such parks to the site of the works.

54. Standardization of design

1. The general types and design of works will be in accordance with the principles given in this volume and the Manual of Field Engineering. Certain modifications may be necessary owing to the situation and material, labour and time available for construction. These modifications must be decided by the senior engineer officer responsible for the system, in consultation with the formation in charge of the work, and it must be clearly understood and insisted on that no other variations from the type plans are to be made, except such small changes as may be necessary owing to the site of any particular work. This will facilitate bulk production of standard components, scantlings, etc., in base and other workshops.

2. The senior engineer officer responsible for the system will have a drawing office in which type plans can be rapidly reproduced for issue to sectors and to units employed on the work. Unless uniformity of type is maintained throughout a system, there is certain to be loss of time and waste of labour and material.

55. Records and nomenclature

1. *Preparation of maps.*—During the construction of a defensive system it is necessary to arrange that maps are simultaneously prepared showing the work done, which maps can quickly be made available for issue to the troops in the event of the occupation of the system.

In order that these maps may be prepared, C.R.Es. must

keep careful records of the progress of the work in their sectors ; this progress must be reported daily to the C.E. by means of slip tracings showing the day's progress. From these reports the C.E. will keep up-to-date maps of his sectors. It is advisable to have three copies of these maps, which should be squared for reference with 4-inch squares. No. 1 copy should remain with the C.E. and be amended daily in accordance with information received. No. 2 and No. 3 copies should be sent alternately to the senior officer responsible for the system, being made up to date before despatch ; from them the senior engineer officer responsible for the system can compile a complete record map showing the progress of the work on the whole line.

2. *Air photographs.*—It is very useful to obtain air photographs of the system while work is in progress, as from them corrections of detail can be quickly and accurately made on the maps.

3. *Trench maps in large quantities.*—When necessary, trench maps can be prepared in large quantities by a field survey company, R.E., from tracings of the record map of the senior engineer officer responsible for the system. The scale used for the maps must, therefore, be that of the maps which will be issued to the troops. This will usually be 1/25,000, on which scale sufficient detail can be shown.

4. *Naming of trench systems.*—The different parts of the trench system must be named. This naming should be done and notice boards should be erected as soon as the trenches are traced, so that every trench may have a name from the beginning. As far as possible, trench names should have reference to existing names in the locality, and each name should apply to 1,000 to 1,500 yards of trench. Changes in the names of trenches should be made at points where communication trenches enter.

56. Excavating machinery

1. *Economy of labour.*—The preparation of a defensive position entails the employment of a large number of men, who may have to be supplied from the troops in the field. The use of mechanical excavators under suitable conditions may result in a great economy of labour.

2. *Scope for use.*—The use of mechanical excavators in the forward areas is not usually practicable, as the likelihood of the machines being put out of action is so great that an inordinate number of machines, or troops to carry on in case of a break-down, must be provided. In back areas, however,

there is great scope for the employment of machinery. Excavation of communication trenches, cable trenches and trenches for water supply and drainage is the class of work for which machinery is successfully employed in civil practice, though, for military purposes, it is probable that the laying of buried cables will be carried out, where the soil is suitable, by some form of thrust-boring machinery, such as that described in Military Engineering, Vol. IV. Shallow burying, up to 3 feet 4 inches, of single cables can be done by a *mole-drainer*, which leaves little trace of the trench; but it requires greater tractive power than is likely to be available (4-ton draw-bar pull in fairly light soil).

Excavating machinery can also be used for the rough cutting of fire trenches, which are afterwards improved by manual labour.

3. *Types.*—Existing machinery for trench work and general excavation for military purposes may be divided into three categories :—

i. The multiple-bucket type.
ii. The plough type.
iii. The single-bucket excavator.

4. In the multiple-bucket type the excavation is done on the dredger system by a revolving chain of buckets, and the spoil is delivered to one side of the trench by a conveyor. The machines are mounted on caterpillar tracks to enable them to travel over rough ground and can dig clean-cut trenches with vertical or sloping sides. A typical machine on the bucket system is capable of digging a trench 3 feet by 3 feet at a rate of 150 feet an hour; the digging rate, however, depends greatly on the soil.

5. The plough type affords a rapid method of cutting a rough shallow trench, which can quickly be improved by hand. A Fowler's trench-plough requires a draw-bar pull of 10 to 14 tons and can at present only be drawn by a heavy tank. A crew of six men is required for the tank and plough.

The present dimensions of a trench cut by this method are 3 feet deep by 3 feet wide at ground level, the actual excavation being roughly of a U form. The soil below the U is loosened to a further depth of 1 foot by special cutters, so that the trench may more easily be improved by manual labour into a fire or communication trench. The rate of progress on a curved trench is 500 yards an hour and the radius of the sharpest curve is 26 feet. Any trace can be cut by lifting the plough; the time required to lift it and change direction is two minutes.

The plough type will excavate a trench giving a certain

amount of cover much more rapidly than the bucket type; it is, therefore, specially useful for emergency work such as the connecting up of a defence system on the outbreak of war or for cutting trenches to give retreating troops something on which to reform. It is also suitable for the construction of dummy trenches and for road and drainage work.

6. Single-bucket excavators are very valuable for big jobs of excavation of a straightforward nature. The three leading types are :—

i. Power shovels or navvies.
ii. Power drag lines.
iii. Grabbing cranes or clam shells.

7. The power shovel embodies the principle of hand shovelling. It consists of a shovel or bucket on the end of a radial arm suspended from a jib. The bucket takes a radial cut away from the excavator and digs above the level on which the machine stands.

This type is particularly useful for making a cutting through a hill for a road or railway, for forming escarpments as anti-tank obstacles or for making a level site behind a hill for a store or ammunition dump. It can also be used for trench digging, but in this case an extra long bucket arm is necessary, so that digging can be carried out below the level of the machine. For this purpose a back-acting shovel is best, so that the machine can stand on undisturbed ground and any danger of the sides of the trench caving in is avoided.

8. The power drag-line excavator scoops the soil up towards itself from below.

It is not so efficient as the shovel, but it can be used for certain work where the latter cannot be used, *i.e.* for excavating in water or where the excavated floor is not hard enough for a shovel to stand on, or for digging narrow cuttings or trenches with insufficient width for a shovel to revolve in.

9. The grabbing crane is fitted with a bucket consisting of two half-scoops hinged together in such a way that they can be closed to dig or to pick up loose material. The grabbing crane can operate both above and below the working level of the machine.

10. The two latter types are both adapted to the making of excavations for big jobs on varying levels, such as would be required for the concrete upper works of redoubts or strong points.

Various patterns of power excavators, with their output capacities, are described in Military Engineering, Vol. VII, 1934, Chapter XXXV.

57. Aerial ropeways

1. In mountainous country, marsh land or a district intersected by numerous waterways a ropeway can be constructed much more easily than a road or light railway. It provides an economical and efficient means of carrying small loads across any ground by the shortest route, *e.g.* for bringing aggregate from a quarry to the site of the work or for disposing of the soil from a deep level working.

Ropeways are of two types :—

i. The bicable, in which the load is supported on a fixed rope and moved by a separate hauling rope.

ii. The monocable, in which a single endless rope both supports and moves the load.

2. The monocable, being the simpler and more portable, is the more generally used for military purposes, and light aerial ropeways on this principle were found very useful during the Great War. Compared with other methods of transporting material they were found to be less visible from the air and less liable to interruption by shell fire. The most useful form is of transportable type, which can be readily moved from one job to another. For this the trestles and terminals can be built up of commercial tube steel scaffolding, the cross-pieces, struts, etc., being joined by special steel clips.

3. Various types of aerial ropeways are described in Military Engineering, Vol. VII, 1934, Chapter XXXIV, which should be referred to.

58. Concrete mixers

1. Efficient mixing of the cement, water and aggregates is one of the most important factors in the production of concrete. So far as quality is concerned, no concrete mixer can improve on the result obtained from systematic and skilled hand-mixing, but really skilled hand-mixing is rare and the process is necessarily very much slower than mechanical mixing. Where large masses of homogeneous concrete work are required, *e.g.* in the construction of heavy machine gun emplacements, shell-proof accommodation, etc., concrete mixers of the batch type should be made use of. The best pattern for general use in the field consists of a revolving drum, with a discharge spout, connected to a radiator-cooled petrol or C.I. engine, mounted on a road truck. These can be obtained in standard sizes from 3 cubic feet to 2 cubic yards mixed batch capacity.

2. A large transportable batch mixer for big jobs of work *e.g.* road making, is the $\frac{1}{2}$-yard batch machine, used extensively in this country. This is fitted with a bucket elevator which will raise sand and aggregate from dumps of material alongside and deliver them into separate compartments in an overhead hopper. The correct quantities for each mix drop automatically into the revolving drum below, while the cement is fed direct into the drum by another band elevator. The concrete is delivered by a shute into a lorry, or it can be dumped direct on the work. The crew consists of three men, and the output is 150 yards a working day of $8\frac{1}{2}$ hours.

PART II.—COAST DEFENCE

CHAPTER VII

HISTORICAL REVIEW

59. Gibraltar

During the siege of Gibraltar (1782) a combined French and Spanish fleet made an attack on the defences of the fortress. The attacking fleet consisted of 47 sail of the line, 10 battering ships and numerous small craft. The battering ships, which mounted 212 guns between them, were cased in timber and roofed over with strong rope-work netting covered with hides and laid at so steep a pitch as to prevent the lodgment of round shot, which were the projectiles of the period. It was on these special ships that reliance was placed for overcoming the land batteries. The armament of the latter consisted mainly of 32-pounders and 24-pounders, with some howitzers and mortars firing red-hot shot, for the heating of which furnaces had been prepared in the neighbourhood of the batteries. The attack opened at 10 a.m., and the fighting was sustained with great vigour by both sides throughout the day. It was some hours before any impression could be made on the battering ships, but late in the afternoon one of them took fire and before long others were in a similar plight. The batteries continued to maintain their fire of red-hot shot all night, and during the following morning the whole of the ten battering ships were either blown up or burned to the water's edge. This ended the action, as the hostile line-of-battle ships had not ventured to engage the shore batteries, no doubt in view of the contingency of meeting the British fleet, and withdrew from the bay.

60. Napoleonic wars

During the Napoleonic wars (1792–1815) few instances occurred of ships engaging shore defences. A few cases occurred where an attacking squadron, whose heavy armament gave them a great superiority in metal, succeeded in crushing an isolated battery, but, on the other hand, there are several instances where a single battery or tower, containing only two or three guns, repulsed with loss and damage two or three well-armed warships. It is certain that naval commanders of the period seldom accepted the risks entailed

by such undertakings, and Nelson is known to have refused a request for a ship attack on the grounds that "the quantity of powder and shot which would be fired away in such an attack could be much better directed from a battery on shore."

61. Sebastopol

1. The operations against Sebastopol (1854) were opened by an attack on the Russian harbour defences by the allied English and French fleets. The warship of that day was but little in advance of that of the Trafalgar era in offensive power. It was still of wood and its armament was 68-pounder and 32-pounder smooth-bore guns, but shell had begun to be substituted for solid round shot. The principal defences were Forts Constantine (110 guns) and Alexander (90 guns), stone casemated works, one on each side of the harbour entrance and closely commanding it, Fort Quarantine (60 guns *en barbette*), an earthwork on the south side, and Telegraph Battery (5 guns), an earthwork, and Wasp Battery (8 guns), a masonry tower, on the north side. There were also several powerful batteries from 500 to 1,000 yards up the entrance channel which were not engaged.

2. The French vessels, of which there were 14, anchored at an average distance of about 1,500 yards from Forts Alexander and Quarantine on the south side of the entrance. These ships mounted in all 1,288 guns of all kinds, of which half could be brought to bear simultaneously in broadside. The forts opposed to them replied with 73 pieces in all, namely, 33 from Fort Quarantine, 17 from Fort Alexander, and 23 from Fort Constantine on the north side of the channel. Of the British vessels, 5 anchored about 1,300 yards from Fort Constantine and engaged it with 260 guns on their broadside, receiving the fire of 18 guns from this fort and also of 36 from Forts Alexander and Quarantine at a range of about 1,700 yards. Four more British vessels, taking advantage of a dead area, were able to approach to within 900 yards.

3. Thus the weight of metal was overwhelmingly on the side of the ships. Notwithstanding this, the defences suffered but little. Fort Constantine, part of which was taken in reverse by British ships, had a number of guns silenced and considerable casualties, but in the other works very little permanent damage was done ; the total Russian casualties were only 138 killed and wounded. The ships, on the other hand, suffered severely. Six British ships were put out of action, mainly by the fire of Telegraph and Wasp batteries, works of poor design and weakly armed, and had to withdraw

in a seriously damaged condition. Some of the French vessels also suffered damage and took fire. The casualties of the allied side were 527 killed and wounded.

4. Although the allied fleets had succeeded temporarily in silencing a number of the defence guns, yet, when they began their withdrawal in the evening, a heavy fire was again developed against them. Both fleets retired during the night, and no further efforts were ever made against the sea front of the fortress.

62. American Civil War

1. *Charleston.*—The American Civil War saw the first iron-clad vessels in action. Although less vulnerable to the projectiles of the shore batteries, they were not appreciably more effective in reducing them. An attack on the forts protecting the port of Charleston was made in April, 1863, by a Federal squadron consisting of one iron-clad frigate, mounting fourteen 11-inch smooth-bore guns and two 8-inch rifled guns, seven armoured monitors, each armed with one 11-inch and one 15-inch smooth-bore gun, and one armoured monitor, armed with two 11-inch guns.

The defences of the port consisted of a number of powerful forts and batteries guarding all the channels ; the principal were Fort Sumter, on a small island in the middle of the main channel, with two tiers of guns in strong masonry casemates and a third tier *en barbette* on the roof, 78 guns in all ; Fort Moultrie, a brick fort of 52 guns, on the north side of the entrance ; and Fort Wagner, an earth battery of 12 heavy guns, on the south side. Against the 32 heavy guns which the attacking squadron carried, the defence works could bring 76 heavy guns to bear on the approaches.

It was the intention of the attacking squadron to force its way past the batteries, but in making the attempt it encountered obstructions which had been laid in the channel and the line was thrown into disorder under heavy fire from the batteries. After 40 minutes' heavy firing, the attacking squadron was withdrawn, five of its ships having been wholly or partially disabled, one of which sank the next morning. Very little damage was done to the defences.

Land operations against Fort Wagner and the other works on the south side were then undertaken, which resulted in their capture some months later. A heavy bombardment was developed against Fort Sumter from batteries established on shore ; although this bombardment, which took part of the work in reverse, caused great damage, the attackers never succeeded in capturing the fort, and Charleston remained in the hands of the Confederates till the army of Sherman

approached it from the land side in February, 1865, when it was evacuated.

2. *Wilmington.*—Fort Fisher, which was constructed during the war in order to command the approach to the port of Wilmington, was twice attacked by a combined naval and military force. The work, which was constructed of sand-bags, was composed of two straight faces at right angles to each other ; one of these, mounting 17 heavy guns, faced the land approach, and the other, mounting 54 guns, faced the sea. The guns fired *en barbette* and were separated from each other by strong traverses. Shell-proof cover for the garrison existed. It was so sited that ships could enfilade the land front at short ranges.

At the first attack, which began at 11.30 a.m., a squadron of 33 Federal ships, including three iron-clad monitors, which anchored 900 yards from the flank of the land face, opened a bombardment on the fort at a rate of 115 rounds a minute. After 1¼ hours the defence guns had become silent and the bombardment was lessened in intensity, but continued till 4 p.m., when it ceased. The next morning at 10 a.m. the bombardment was renewed and methodically kept up for seven hours, while a force of 3,000 soldiers were landed to the north of the fort. At 5 p.m. this force advanced to attack the land face, which was also subjected to a concentrated enfilade fire from the ships. This fire, however, had to be suspended just before the actual assault, with the result that the garrison was able to man its parapets and repulse it. The reports of the attackers stated that the fort was "substantially uninjured as a defensive work."

At the second attack, about three weeks later, the landing force was 8,000 men, who were provisioned for 12 days. The bombardment was heavier, 44 ships, including four monitors and an iron-clad frigate, taking part in it, and was longer sustained. Nevertheless, even on the second day of the bombardment, the Mound Battery of the fort could not be prevented from answering most gallantly. The land attack was pushed with determination, and a body of seamen and marines made a simultaneous landing and assault on the sea face. The attempts of the latter were repulsed, but the land column succeeded in getting a footing in the fort and after several hours of hard fighting captured it.

63. Alexandria

After the American Civil War there were very few instances of naval attack on shore works till towards the end of the century. At the bombardment of the defences of Alexandria by the British fleet (1882) the conditions were very favourable

to the ships, as the works and armaments of the former were ill-designed and antiquated and their personnel untrained and badly organized. Eight battleships and six gunboats fired a total of 3,198 projectiles from their guns of all calibres. The forts replied for some time, but gradually their fire was silenced and the gunners abandoned their guns. On the following morning, as soon as the bombardment reopened, the white flag was displayed and the forts surrendered. Out of nearly 300 pieces of various kinds which the works contained, approximately 20 only were dismounted or otherwise permanently injured and very little damage was done to the earthworks, of which most of the works were composed. Several of the ships received a number of hits and suffered minor damages. There is little doubt that the ships would have been severely damaged if the enemy's defence had been better organized and disciplined.

64. Spanish-American War

Although the armament of the Spanish coast defences (1898) was weak and antiquated, the American ships made no attempt to attack them seriously. The works at Havana, which were the most formidable, were never engaged at all. The obsolete defences of Santiago were bombarded on several occasions with no appreciable result, and the same occurred once to the defences of San Juan Porto Rico. This abstension from serious naval attack was no doubt due to orders issued by the U.S.A. Government that the ships were not to be risked.

65. Port Arthur

Although the capture of this port (1904) was of vital importance to the Japanese, in order to deprive the Russians of their only naval base in eastern waters, its reduction was left almost entirely to the land forces, and care was taken not to expose capital ships to the fire of the coast defences. Several bombardments by ships took place, but they were either at ranges beyond those of the guns of the defences or were discontinued as soon as the defences developed a reply. On one occasion the FUJI received a hit near the stern from a 10-inch shore gun and the whole squadron at once withdrew. No damage was done to the coast batteries by any of these bombardments. One or two determined efforts were made by light craft and old merchant vessels to blockade the entrance to the harbour, but the guns and searchlights of the defence were able to prevent this from being successful.

CHAPTER VIII

THE GREAT WAR

66. Attacks on British coast defences

1. Only one case occurred during the entire war of an attack by German ships on a British defended port. On 16th December, 1914, three German cruisers engaged the defences of West Hartlepool at a range of 4,000 yards, having approached under cover of mist. The armament of the port consisted only of three 6-inch guns.

2. The action lasted 42 minutes. The ships were too heavily armoured for their hulls to be damaged by the 6-inch guns of the defence, which, however, inflicted considerable damage to their upper works and caused casualties in the ships. The shore batteries were uninjured and there were no casualties; in various defence posts, outside the batteries, 7 men were killed and 21 wounded. The guns were ranged mainly by their automatic sights, as the range-finding station, which was sited close to the batteries, was so shaken by the concussion of the enemy's projectiles that it was practically useless.

67. The Dardanelles

1. *Description*.—The Dardanelles (Plate **23**) is a narrow strait, about 20 miles long, connecting the Mediterranean with the Sea of Marmora and forming the approach to Constantinople, which in the war was a place of peculiar strategical importance. The narrowness of the channel, which is only about 2,000 yards at its narrowest part, confers on it exceptional potentialities for defence.

The defences were on both sides of the channel and in three groups, viz. :—

i. The outer defences, at the Mediterranean entrance to the Straits.
ii. The intermediate defences, covering the minefields.
iii. The inner defences, at the Narrows and inside them.

2. *Initial armament*.—When Turkey entered the war (November, 1914), the armament was as follows :—

Group i.—23 guns (19 of 15-cm. (5·9-inch) calibre and upwards), 4 12-cm. (4·7-inch) howitzers. Of the guns all except 5 were old-pattern short guns.

Group ii.—14 W.F. guns, from 4·7-cm. (0·18-inch) to 15-cm. (5·9-inch) and 3 batteries each of 4 mobile field guns.

Group iii.—72 guns, from 15-cm. (5·9-inch) to 35·5-cm. (14-inch) of which 52 were old pattern short guns, together with 7 15-cm. (5·9-inch) howitzers and 6 21-cm. (8-inch) mortars.

3. *Design of batteries.*—Nearly all the works were antiquated and also faulty in conception and design. The batteries were mostly at low levels and the guns fired through wide-mouthed embrasures separated by traverses of inferior masonry covered with earth in geometrically perfect slopes. Most of them were very conspicuous. The guns were generally massed together in batteries, which in many cases could be enfiladed from the sea. There were neither shields for the guns nor shell-proof cover for the personnel. There was a lack of organization in tactical units and the systems of range-finding and fire observation and control were inadequate and inefficient.

4. Five lines of mines had been laid in the Narrows, and the minefields were commanded by the guns of groups (ii) and (iii).

5. On 3rd November, 1914, a short bombardment of the outer group of defences was carried out by four Allied battleships, with a view to ascertaining the extreme ranges of the defence guns. Considerable damage was done to Fort Sedd-el-Bahr ; its magazine was exploded and its guns were put out of action. Practically no damage was done to any of the other works. The ships were not hit, as they were beyond the range of the shore guns.

6. *Additional armament.*—The Turks took immediate steps to repair the damage and also mounted a considerable amount of additional artillery. The latter included a few modern 15-cm. (5·9-inch) guns and also a number of howitzers and mortars, which were located in concealed positions and intended to attack ships by high-angle barrage fire, and so prevent them from taking up positions inside the Straits. By the end of February, 1915, they had the following additional armament :—

28 15-cm. (5·9-inch) howitzers.
4 12-cm. (4·7-inch) howitzers.
9 15-cm. (5·9-inch) guns.
12 12-cm. (4·7-inch) guns.
18 21-cm. (8-inch) mortars.
6 15-cm. (5·9-inch) mortars.

7. Four additional lines of mines were also laid and the armament covering them was greatly increased until, by the end of February, it consisted of :—

On the European side : 17 fixed and 30 mobile guns.
On the Asiatic side : 16 fixed and 24 mobile guns.

The searchlight defences were also considerably augmented.

8. The deliberate attack on the defences was begun by a bombardment of the outer group of works on 19th February. In this and subsequent operations 12 battleships and a number of smaller vessels were employed, besides trawlers for mine-sweeping. Of the battleships all except three were armed with 12-inch guns, two had 10-inch and 7·5-inch guns and one had 15-inch guns.

9. The bombardment of the outer defences on the morning of 19th February began at long ranges with the ships under way, but it was soon found that sufficient accuracy of fire was unattainable while they were moving ; consequently all the ships anchored at ranges beyond those of the shore batteries. Early in the afternoon some of the ships closed on the forts with the intention of employing their secondary armaments, but the forts, which had till then been silent, opened fire. Failing light put an end to the operations and bad weather prevented their renewal for several days.

10. The next attack took place on 25th February. The long-range bombardment resulted in the silencing of the outer forts and in the afternoon some of the ships closed in to short ranges and subjected them to further shelling, after which they appeared to be abandoned. One of the attacking ships was hit seven times and others were forced to keep moving to avoid being hit. During the following days (26th February to 3rd March) parties of seamen and marines were landed on both sides of the entrance and succeeded in destroying all the guns of the outer defence group that remained serviceable. It was found that the long-range bombardment had caused the permanent disablement of 4 guns only. A considerable number had been put temporarily out of action, but about 70 per cent. appeared still to be serviceable. The demolition parties destroyed 46 guns of all calibres.

11. The outer defences having thus been entirely overcome, attempts were next made to silence the batteries of the intermediate group of works by the fire of ships which entered the Straits for the purpose. The intention was to overcome them sufficiently to admit of sweeping passages through the minefields to enable ships to approach the Narrows and engage the defences of the inner group. For several days the efforts continued, but the ships were compelled to be continually on

the move by the fire of well-concealed and dispersed howitzers. From this cause and from the difficulty of locating the targets of the intermediate group, they did not succeed in their object. Repeated attempts were made during the first fortnight of March to sweep the minefields, but the defence lights and armaments made success hopeless and it was decided that, before they could be cleared, the ships must reduce the batteries to silence.

12. In the meantime the Queen Elizabeth had been carrying out a bombardment of the works in the inner group at the Narrows by the indirect fire of her heavy guns (15-inch) over the Gallipoli Peninsula at 14,000 yards' range. Observation of the fall of shell was at first made by seaplane and afterwards by ships inside the Straits. The observation was not sufficiently accurate to make the bombardment effective and no material damage was done, though there was some moral effect, owing to the fact that the works aimed at were unprotected from fire from this direction.

13. On 18th March another fleet attack was delivered on the defences. The intention was to silence the defences of the Narrows and of the minefields simultaneously, so as to enable the sweepers to clear a passage through the outer lines of mines. Sixteen Allied battleships took part in the operation. Firing began at 11 a.m. and was hotly maintained by both sides for a considerable time, several of the ships sustaining hits. At 1·54 p.m. the French battleship Bouvet struck a mine and quickly sank. By this time the fire of the defences had slackened and the minesweepers were ordered to advance. On attempting to carry out their task they encountered heavy fire which prevented their doing so. At 4.15 p.m. the Irresistible and the Inflexible both struck mines and the former had to be abandoned and subsequently sank. It then became evident that the area over which the ships were operating was insufficiently swept and the battleships were ordered to withdraw. Another ship, the Ocean, struck a mine at 6.5 p.m. and, being also struck by shell, had to be abandoned and sank. Besides the Bouvet, two other French ships had been badly damaged by gunfire.

14. The effects on the defences were very small. Hardly any permanent damage was done to guns ; some ammunition dumps and expense magazines were exploded and some barracks destroyed ; the strength of the defence as a whole was not seriously impaired and the minefields and their defences were left practically intact.

15. *Abandonment of naval action.*—This was the last effort made to reduce the defences by naval action and it was

decided to undertake military landing operations with the intention of capturing the Kilid Bahr Plateau, which dominated the forts on both sides of the Straits.

16. *Organization of defences.*—It is worth while to note that the Turkish defences of these Straits were organized in three groups, viz. the outer, intermediate and inner defences. The outer defences completely fulfilled the functions of a forward zone by resisting minor attacks and necessitating the development of a strongly organized attack before they could fall. By this means they gave ample time for reinforcing and strengthening the main position. Moreover, their distance from the latter was such as to necessitate a fresh operation for the attack on it, which could not be undertaken without bringing the ships inside the Straits and into positions where they were exposed to the fire of the heavy artillery positions in rear. The main position consisted of the successive lines of obstruction in the form of mines, well covered by cross-fire from concealed guns. In rear, again, were the inner defences at and above the Narrows, with heavy artillery supporting the main position.

The conformation of the Straits and the narrowness of the channel afforded a particularly favourable opportunity to bring cross-fire at close range on the attack.

68. The German defences on the Belgian coast

Description

1. *Reasons for fortifying.*—Since the landing of an Allied force on the Belgian coast would have had the effect of turning the flank of the German line of defence on the Western Front, the Germans, as soon as they had occupied the coast, took steps to fortify it strongly against attack from the sea.

2. The coastline was about 32 miles long and almost entirely straight. The north-eastern end joined the Dutch frontier, and the south-western end connected with the German land front. In this stretch were included two small light-draught harbours, Ostend and Zeebrugge; these were connected with the inland canal system and were utilized by the Germans as submarine bases. Before the occupation by the Germans the coast had been entirely unfortified. The immediate interior is dead flat marsh country for a considerable distance, but separating this from the sea is a belt of sandhills, varying in width from 50 yards to about ¾ mile and nowhere over 120 feet high. The water off shore is shallow for a considerable distance, with a few difficult deeper channels.

3. The coast defence system (Plate 24) was developed gradually from the beginning of 1915 onwards. It was

divided into two sectors, with headquarters at Ostend and Zeebrugge, respectively. The works in each sector were mainly in the vicinity of those harbours, which were about 14 miles apart, and, owing to the long range of the guns, the primary batteries of both could give each other effective support. The Deutschland battery (Plate **25**), the most powerful (four 38-cm. (15-inch) guns with a range of 25 miles), was situated almost at the middle of the length of coastline. The sea along the whole of this line for a long distance from the coast was potentially under effective fire.

4. At the end of the war the total primary armament was as follows :—

5 38-cm. (15-inch) guns.
4 30·5-cm. (12-inch) guns.
20 28-cm. (11-inch) guns.
4 29-cm. (11-inch) howitzers.

These were all sited behind the belt of sandhills in low-lying emplacements entirely invisible from the sea, and therefore relied on indirect fire and forward observation. This was a new departure in coast defence practice, according to which, before the war, guns had always been sited as far forward as possible in positions admitting of direct fire over the sights. The new arrangement did not create any dead areas accessible to ships, because the sandhills were very low and also because areas dead to the batteries immediately opposite them were under effective fire from other batteries further along the coast. Moreover, the waters inshore were well covered by the secondary armament.

5. The secondary armament consisted in all of about 60 guns of calibres of 15 (5·9-inch), 17 (6·7-inch) and 21 cm. (8-inch) and about 50 of 10·5 (4·2-inch) and 8·8 cm. (3·5-inch), a few of which were on field carriages. Most of these were sited for direct fire and provided for close defence of the harbours and their approaches.

6. Finally, there was a complete system of defence against landings. A continuous belt of strong wire entanglement was erected along the whole length of the coast, strongly supported by machine guns, field guns, howitzers and trench mortars. Tank stops of various kinds were provided on the coastline in and near Ostend. Another line of machine gun posts, about half a mile inland, provided a second line of defence, and the two lines were connected by several lines of entanglement with trenches and strong points to prevent lateral deployment of a force if it had landed.

7. The guns of the heavy armament mounted in the earlier batteries were in sunken concrete emplacements, which, owing

to the nature of the soil, required foundations built on piles and, in some cases, the use of coffer dams. This type of battery took a very long time to construct (the Deutschland battery took about two years). Later types were on a very different principle. In these the guns were on a special mounting which allowed them to be run into position on a line of standard gauge railway and lowered from their travelling wheels on to a firing pedestal and racer in a few hours. The earlier batteries had shell-proof magazines and expense stores, but the later ones had ammunition stores which gave protection against the weather only.

8. The secondary batteries varied considerably in design. The guns were mostly in low, open, concrete emplacements on the forward edge of the sand dunes, with expense ammunition stores in underground shelters close beside them and similar cover for personnel in the rear.

Plate **26** shows an emplacement for a 17-cm. (6·7-inch) gun with concrete magazine disguised as a farmhouse (brushwood roof and painted windows).

9. The searchlight installation was arranged to illuminate the whole front of both the principal groups of defences as far as the limits of their range allowed. Beyond this range star-shell barrage was used.

10. There was a complete organization for anti-aircraft defence composed of aeroplanes, artillery, machine guns, searchlights, sound locators and kites. The principal gun was the 8·8-cm. (3·5-inch) on a pedestal mounting and there were also guns and howitzers of 7·5 (2·95-inch) 7·7 (3-inch) 10·5 (4·2-inch) and 15 cm. (5·9-inch). A 3·7-cm. (0·15-inch) gun was also used, firing from belts containing 200 rounds each, in which alternate rounds were high explosive and green tracer (known to the British services as " flaming onions.")

Operations against German defences situated on the Belgian coast

11. *Means employed.*—With the exception of the blocking raids on the harbours of Zeebrugge and Ostend, which are described in Sec. **69,** no serious attack from the sea was delivered on the coast defences, nor was any attempt at landing made.

A large number of bombardments at long ranges were carried out at various times with the idea of doing damage to the harbour works, lock gates, etc., and similarly a number of air bombing-raids against them was undertaken. No capital ships were employed in the bombardments, which

were carried out by shallow-draught monitors specially constructed for this purpose and carrying 12-inch and 15-inch guns. On the first occasion the monitors opened fire at 16,000 yards' range, but were soon forced to withdraw by the accurate fire of the defences. Subsequent bombardments were at considerably longer ranges, ultimately at over 30,000 yards, and smoke screens were used to conceal the ships from view from the shore. Aeroplane observation of fire was employed.

12. *Objectives and damage done.*—Most of the bombardments were directed at the harbour works and only a few at the gun positions. Viewed as area bombardment, they were effective in that they harassed the enemy and hampered and restricted the use of the harbours as lying-up places for ships. Ultimately the enemy submarines were driven to lying-up at Bruges, 14 miles inland, and using Zeebrugge only as a means of exit to the sea. No vital damage was done by the bombardments to the locks or other works, and it required blocking raids to put the ports permanently out of action. To have succeeded in this by gunfire alone would have required a prohibitive expenditure of ammunition and entailed the wearing out of the guns before success could have been achieved. Examination of the battery positions after the war revealed no indication of any gun or any magazine having received a direct hit from any of the bombardments from the sea.

13. The shore batteries considerably outranged the guns of the monitors and their fire was accurate even at ranges of well over 30,000 yards. Nevertheless, they did not succeed in registering a direct hit on any of the monitors, except in one of the early actions when one was struck at 18,000 yards ; a yacht was also sunk.

69. Blocking of Zeebrugge Canal

1. The object of this raid (April, 1918) was to block the canal entrance in order to prevent its use by German submarines.

2. *Armament and works.*—The canal mouth is protected by a stone mole, about a mile long and 70 yards wide, curved in plan for most of its length (Plate **27**). The outer side of the mole has a thick wall or parapet, on which were mounted the following guns : two 15-cm. (5·9-inch), four 10·5-cm. (4·2-inch), two 8·8-cm. (3·5-inch) and four 5-cm. (0·2-inch). A portion of the mole at the shore end was built on steel piles instead of solid stone, in order to allow the current to pass

through it and thus prevent silting of the harbour. On the shore, on both sides of the harbour, were a number of batteries of both primary and secondary armament, covering all the near approaches. But the defences against a blockship attack were not good. The guns were not adapted for night firing, as the electric lights were very few in number and did not properly illuminate the approach channel. Far more attention had been paid to man-killing weapons, such as machine guns, than to weapons which could stop ships.

3. The attack was carried out as follows :—

At 11.56 p.m. on 22nd April, 1918, the VINDICTIVE, an old battleship specially strengthened and provided with sandbag and mantlet protection on her decks and upper works, approached the mole under cover of mist and a smoke screen. She was not detected till she was within 200 yards of the mole batteries, and she succeeded, under heavy fire, in getting alongside the mole and landing, by means of specially constructed gangways giving access to the top of the high outer parapet, strong parties of seamen and marines for the purpose of destroying the defences of the mole.

Simultaneously a submarine loaded with explosives made from a westerly direction for the shore end of the mole and jammed herself in the pile-work of the open portion. There the crew abandoned her and blew her up and this formed a wide gap in the mole approach and prevented the arrival of reinforcements to the mole.

Meanwhile three old cruisers, THETIS, INTREPID, IPHIGENIA, filled with concrete and led by motor torpedo boats burning flares, made for the canal entrance. One went aground just off the entrance, but the other two got inside the canal and were sunk across the channel, completely blocking it, their crews being taken off by motor-boats.

The success of this operation was due to the extreme care and foresight with which every detail had been worked out and rehearsed in advance and to the striking gallantry and determination with which it was carried out ; also to the fact that the element of surprise was secured. The VINDICTIVE withdrew in a very damaged condition, but only a few of the men of the landing parties succeeded in getting back.

A simultaneous attempt to block the entrance to Ostend Harbour was not successful, owing to the difficulty of finding the entrance.

The VINDICTIVE was patched up and filled with concrete and a few days later was taken over to Ostend, where she was sunk in the harbour entrance, but not sufficiently across the fairway to form a complete block.

70. Capture of Tsing-tau by the Japanese

Tsing-tau was a heavily fortified port on the northern side of the entrance to the bay of Kiao-chao, which had been leased to Germany by China.

It was attacked by the Japanese, who had landed on the northern side of the Shantung Peninsula, 112 miles away, and they, with the co-operation of a small British force, reduced it by siege methods in five weeks.

Naval assistance was given during the last few days of preparation for the final assault by long-range bombardment from a covered position behind Cape Jaschke to the south-west.

71. Examples of motor torpedo boat attacks

1. *Pola Harbour.*—On 12th December, 1917, two Italian motor-boats, each carrying two torpedoes and fitted with petrol and electric motors (the latter for ensuring silence in approach), attacked Pola Harbour by night. A passage over the boom, which consisted of three lines of nets suspended on 6-inch wire jackstays, was accomplished by hanging weights on two of the lines of nets and cutting the third, the latter operation taking two hours. The boats then torpedoed the battleships WIEN and MONARCH, the former being sunk and the latter damaged.

2. *Kronstadt Harbour.*—On the night of 18th August, 1919, a successful attack was carried out on Bolshevik warships lying in Kronstadt Harbour by eight motor torpedo boats of the British naval forces operating in the Baltic. Four succeeded in entering, through a very narrow entrance, the basin in which the warships were lying and torpedoed two battleships and two other ships.

Simultaneously an air raid was made on Kronstadt and was successful in its object of diverting the attention of the defence from the main attack.

It should be noted that there was no obstruction at the entrance to the basin and that no watch was kept by the flotilla leader on guard outside the basin.

CHAPTER IX

THE COAST DEFENCE PROBLEM

72. Preliminary considerations

1. The term "coast defence," in its broadest aspect, includes all measures, whether naval, military or air, taken for the defence of a coastline against any form of attack. The principles underlying the defence of a coastline are similar to those underlying any other form of defence. Final success cannot be attained by passive defensive action alone ; to remove all danger of attack, victory, which is attainable only by offensive action, is necessary.

2. *Utilization of forces.*—In the case of war with an overseas enemy, this offensive action would be supplied by the navy operating against the enemy's forces, by the army, transported under cover of the navy, operating against the enemy's territories and land forces, and by air forces, either in co-operation with the navy and army operations, or in the form of independent air action by means of shore-based or sea-borne aircraft.

3. *Economy of force.*—In order to fulfil the universal principle of economy of force, it is essential that the offensive forces referred to in para. 2, above, and in particular the navy and air force, should not be required to tie up more than an absolute minimum of their effectives in the passive defence of their own coast.

4. *Limitation of artillery defences.*—The term "coast defence" does not imply the provision of defences to cover all parts of the coast line. Such dissemination of force is impracticable and unnecessary. The defence of a country against invasion from overseas requires the existence of a fleet supported, as necessary, by mobile land forces of all arms distributed at convenient centres, whence they can be brought into action against enemy forces which have landed at any point ; this before the latter have had time to develop superiority of force, to land guns, munitions and accessories which are requisite for a general action, to seize and occupy positions from which they could cover the processes of landing or to secure room for manœuvring. Passive defence works and armaments are required only at such points on the coast as are of primary importance, namely the naval and selected commercial ports.

5. The importance of these ports is due to the following causes :—

i. Such ports must be the first objective of an enemy who attempts an invasion in force, since no such invasion is possible unless the attacker secures at any rate temporary or local maritime supremacy and possession at an early stage in the operation of one or more ports with their facilities for the rapid disembarkation of men, horses, guns and stores.

ii. The security of naval bases with their dockyards is essential to the continuance of the operations of sea-going fleets.

iii. The security of commercial ports is essential to the maintenance of the supply from overseas of food and raw materials, without which the prosecution of war by an island power becomes impossible.

6. Coast defence, therefore, means the defence of ports and anchorages against seaward and air attack. In the case of a world-wide empire with dominions and dependencies in all the principal oceans, it includes the defence of such naval ports overseas as are required to provide bases in war for naval forces operating in distant waters and of those commercial ports overseas of which the importance is such as to justify their defence.

7. *Aircraft.*—Hitherto the term "coast defence" referred to defence against sea-borne attacks. Such attacks may, however, be made in conjunction with attacks by aircraft, and the necessary measures of defence must therefore include defence against attack from the air and entail co-operation of the defender's air forces with his land and sea forces. To meet an air attack directed against inland objectives, the defensive measures will usually be organized inland and will follow the principles described in the Manual of Anti-Aircraft Defence (Army Units).

8. Defended ports are classified as follows :—

i. *Naval ports :—*

(*a*) *Naval repair ports.*—Ports where facilities are established by the Admiralty for repairing H.M. ships and where depots of men, ammunition and stores are (or can be) maintained. Certain naval repair ports are also dockyard ports, *i.e.* a naval port where the Admiralty are vested with powers of control by an Order in Council made under the Dockyard Ports Regulation Act of 1865.

(*b*) *Naval anchorages.*—Harbours which are used by the fleet in peace and in war.

ii. *Defended commercial ports.*—Ports in which the volume of mercantile shipping or the national importance of local industry is sufficient to warrant protection against attack. They may be divided into :—

(*a*) Mercantile ports.

(*b*) Ports for fuelling, supply, arming and providing defensive equipment of merchant vessels.

(*c*) Convoy assembly ports.

9. The term "port of refuge" applies to all defended ports, whether naval or mercantile. A naval port should only be called a "naval base" when it is fulfilling that function in a campaign.

10. The term "coast fortress" is often used for brevity to indicate a defended port of any class and, where so used, it includes all the works and military establishments under the command of the fortress commander and the whole of the area directly defended by them.

73. Evolution of modern coast defences

1. One of the principal factors in attacks on a defended port is the combat between the attacking ships and the shore guns. As in the case of land defences, so also in coast warfare, past history shows a continuous process of contest between weapons of attack and materials of defence. The parallel, however, is not complete. Ships are, and must be, designed to fight ships and not, primarily, to engage shore guns. Owing to the nature of the element on which they move, they can carry their own material protection in the form of armour. The contest for predominance between the gun and the armour has developed in relation to combat between ship and ship to a large degree, irrespective of the requirements of coast warfare.

2. The broad principle underlying the design of coast defence works is exactly the same as that stated in Part I of this volume as governing the design of land defence works, namely, that they should admit of the fullest possible development of the power of the weapons of the defenders and, conversely, that they should restrict to the greatest possible extent the power and effect of those of the attackers.

3. When ships were of wood and their guns were smoothbore of short range and of low destructive power, castles and towers of stone or brick afforded adequate protection to the shore guns and also gave security against capture by land attack. In the earlier forms of protection the guns were generally concentrated in batteries, mounted *en barbette* and fired over a low wall or bank.

4. At the end of the eighteenth century a first-rate line-of-battle ship carried so many guns that, in weight of metal

and rapidity of fire, she could outmatch the shore battery of that day. For instance, a three-decker of that period might have had 66 guns on each broadside. Such a vessel could fire 330 rounds, of an aggregate weight of over 12,000 pounds, in five minutes. When opposed to a shore battery firing from open emplacements, she could, provided that she could get within range without injury, crush it by sheer superiority of metal and rate of fire.

5. The above conditions, together with the supersession of round shot by shell, brought about the necessity for firing through embrasures and soon developed the stone fort with casemates, of which numerous examples still exist. In order to compete with ships in volume of fire, forts were built with two or three tiers of guns. This resulted in overcrowding of the armament and the two or three-tiered forts were targets of greater size though of less vulnerability than those offered by ships.

6. The introduction of rifled artillery, with its increased penetrative power, led to the introduction of armour for the protection of ships and also to the adoption of iron shields for the fronts of the gun casemates of forts. Examples of this type of work are to be found in Garrison Point Fort, Sheerness ; the Hoe, Darnet Forts, and elsewhere.

7. A further development in the same direction was the complete iron fort, armoured all round, such as those at Spithead, Plymouth and Portland, thus producing a close approximation to a stationary battleship.

8. Besides the obvious tactical disadvantages of defence of this type, another factor arose, which tended to put an end to the dependence on armour for the protection of shore guns. The general industrial progress which took place in the second half of the nineteenth century brought about rapid developments in the range and power of artillery.

It became evident that the practice of building very costly armoured forts, which became obsolescent when a more powerful type of gun had been evolved, would lead to prohibitive expense.

These considerations led to the necessity for finding other means of fulfilling the principle of restricting the power and effect of the weapons of the attack.

9. As a result of this, the casemated fort gave way to guns firing from open batteries. At first the desire for a high degree of protection for the personnel led to the device o disappearing mountings, enabling all the operations of loading to be carried out below the level of the parapet and under cover of a horizontal steel shield. Several types of disappearing mountings were designed and introduced ; in the

earlier ones the mechanism for raising and lowering the gun was a counterweight device and in the later ones it was hydro-pneumatic. The latter was mechanically efficient and a number of guns on those mountings was provided in coast works between the years 1880 and 1890.

10. The disappearing mounting, however, soon became obsolescent. It required special care in maintenance, was liable to get out of order and was difficult to repair, but its real defect was its slow rate of fire.

The last decade of the nineteenth century saw the advent of the quick-firing principle for guns of 6 inches and under on ships and a considerable acceleration of the rate of fire of heavy guns. To compete on equal terms with the superiority in numbers of guns which an attacking squadron of ships could bring to bear, it was essential that the guns on the shore batteries should be capable of an equal rapidity of fire. The fleeting nature of the target presented by attacking vessels was another reason why speed and accuracy of fire should be of greater importance than material protection of the piece or of the personnel.

11. The open emplacement, which facilitates rapid fire, has been the only type constructed since the end of the nineteenth century.

Rapidity and accuracy of fire have been furthered also by the invention of automatic sights, which facilitate rapid ranging at the shorter and critical ranges. The open emplacement, moreover, by virtue of its wide arc of fire, ensures the fullest development of the power of the defender's weapons.

12. For protection of the gunlayers and loaders, and of the recoil cylinders, sighting gear, etc., steel shields are provided which are proof against bullets and shell splinters but not against a direct hit by a shell, which alone is capable of putting a gun out of action. The chances of such a hit are reduced by the dispersion of the batteries and gun emplacements and to some extent by their concealment, both by judicious selection of their site and by artificial means. Moreover, the acceptance of the risk entailed by the abandonment of the material protection of armour is further justified by the inherent advantages which artillery in fixed defences on shore possesses over guns in ships.

13. In the later years of the Great War 12-inch guns on naval turret mountings were emplaced for coast defence purposes at two points on the North-East Coast. These were operated entirely by electric and hydraulic power. Each unit was self-contained, having its magazine and engine room below the gun platform, and the ammunition was delivered to the latter by power-driven hoists.

74. Ships versus coast defences

1. In the combat between ships and shore defences the former have certain marked disadvantages, most of which are inherent and arise out of the nature of the element on which they operate. The progress of invention has up to the present tended to increase the advantages of the defences, but it is possible that future developments may to some extent modify the relations between the two.

It is now possible for a ship, masked by a smoke cloud, to maintain accurate fire on a shore battery. Further, an effective bombardment can be carried out by a ship in motion, even when changing course and speed, which makes it a difficult target on which to register hits. Again, the increase in range of naval guns allows fire to be opened when a ship is " hull down " to the observation post on shore, unless the latter has the advantage of high command, such as can be found at Gibraltar or Hong Kong. Further, local air supremacy, affording accurate spotting and reconnaissance, has a very considerable bearing on the problem.

2. The disadvantages mentioned in para. 1, above, under which ships engage shore defences, although modified in some degree by recent innovations and developments, are due to the following :—

i. The platform.
ii. The target.
iii. Ranging facilities.
iv. Observation of fire.
v. Armament and ammunition.

3. *The platform.*—Ships' guns fire from an unstable platform, which is very rarely unaffected by wave action. The long ranges of the present day accentuate this and at a range of 20,000 yards a movement of 15 seconds in any direction is sufficient to throw a ship's gun off the small target offered by a shore gun. The latter, with its steady platform, therefore, has a decided advantage in accuracy for this reason.

4. *The target.*—Since nothing but a direct hit on the gun or mounting will put a shore gun out of action, the vulnerable area is very small. The vertical area of the target offered to a direct hit is approximately as under :—

6-inch gun, end-on about 20 square feet
6 ,, ,, broadside, about 40 square feet.
9·2 ,, ,, end-on, about 50 square feet.
9·2 ,, ,, broadside, about 120 square feet.

A battleship, on the other hand, offers to the shore gun a target about 30 feet high and 300 to 400 feet wide when broadside on, and a still more favourable one when end on,

owing to the fact that inherent errors of the gun are greater as regards range than as regards direction. It is true that a considerable portion of this target is armoured, but not all of it has armour which will resist heavy armour-piercing shell and hits on the upper works and funnels may so damage the control arrangements or reduce the steaming capacity as to necessitate withdrawal from action.

In the matter of visibility also, the target offered by a ship is more favourable than that offered by a shore gun, which, by judicious siting and arrangement of surroundings, can be made most difficult to detect by direct observation from the sea.

5. *Ranging facilities.*—All range-finders require a fixed base, and the longer the base the greater the accuracy. On a ship the length of the base is necessarily very limited, but on shore bases can be much longer and advantage can usually often be taken of high ground for observing stations. Shore guns are therefore likely to be more accurately controlled than those on ships. Certain improvements, however, have been made in the method of range-finding and fire direction both ashore and afloat, and the science of aerial observation has also advanced both in the type of machine and the instruments used. It is probable, however, that in spite of all modern improvements the balance of advantage will remain as heretofore in favour of the shore gun.

6. *Observation of fire.*—The fall of shot is more easily observed on the sea than on the land, where it is liable to be obscured by trees, buildings, etc. But here again air-spotting will materially help a ship's observation of fire.

7. *Armament and ammunition :—*

i. Ships' guns, being designed primarily to engage other ships and to pierce a considerable thickness of armour, are necessarily of high velocity and flat trajectory and are therefore not so effective against the targets offered by modern coast defences. At long ranges, however, this disadvantage will be somewhat modified by the necessary increase of elevation given to the gun, with the resultant steeper angle of descent of the projectile.

ii. Similarly, the projectiles and fuzes normally used by ships are not the type best suited for use against coast defences. It may be assumed, however, that a warship destined for coast bombardment work would be equipped with a proportion of H.E. shell fitted with suitable fuzes. In special cases, where monitors are used and there is little fear of a naval encounter, the bulk of the ammunition carried will be such as is suitable for the destruction of defence works.

iii. *Ammunition supply.*—Owing to the many factors that

affect shooting, *e.g.* wind, atmosphere, wear of the gun, condition of the propellant, etc., only a small percentage of rounds fired can be expected to hit a small target, even under the most favourable conditions as regards stability of platform, accurately known range, etc. When ships attack shore defences, a very great expenditure of ammunition is therefore inevitable. A ship, however, can only carry a limited supply, and to replenish it may necessitate a return to its base, an operation possibly of some days. Shore guns, on the other hand, are not as a rule so limited in the amount of ammunition that can be stored in their vicinity, and its replenishment presents, in most cases, no difficulties. It is possible, however, in distant parts of the Empire, *e.g.* the Far East, some economy might have to be exercised in the expenditure of the ammunition available, in view of the uncertainty of its early replacement.

75. General conclusions

1. From a review of the history of the past, as well as from the limited experience of the Great War, certain general conclusions may be drawn which will form a guide to the probable future developments of coast defence.

2. The attack and defence of ports can no longer be considered as an amphibious operation, but one that is conducted in the three elements of land, air and water, and of these it is probable that in the future the air will bear a prominent part.

3. Owing to the difference in the size of the target and the advantage derived from a stationary and fixed platform, the land gun should register a considerably higher percentage of hits than the ship's guns on the batteries of the fixed defences.

4. Comparatively few examples will be found in modern history of ships engaging shore defences, and still less of such efforts being successful, even when the shore defences were of a low order of efficiency. As previously stated, ships are designed to fight ships. It is evident, therefore, that a naval commander will only in very exceptional circumstances accept the risks of employing capital ships against shore defences, in view of the considerable odds against them and, in particular, of the fact that they might after such an operation be required, with depleted magazines and in damaged condition, to engage the intact ships of the enemy. Furthermore, the same results may, in certain localities, be attained more economically by the use of aircraft.

5. To gain possession of a properly defended port by naval and air attack unaccompanied by land attack is, under present conditions, not a practical proposition.

CHAPTER X

FORMS OF ATTACK

76. Introductory

Before consideration is given to the forms and methods of defence and the works required in connection with them, it is necessary to enumerate the various forms of attack that may be undertaken against a defended port. These are :—

i. *Sea attack.*—In the case of a naval port this may be directed against vessels lying in harbour or in dock, dockyards with their workshops, floating docks and magazines, and stores and depots of all kinds. In the case of a commercial port, the main object of sea attack may be the destruction of dock and lock gates, and of valuable resources such as fuel oil installation, and damage to mercantile shipping. In either case an attempt may be made to block the entrance.

ii. *Air attack.*—This may be delivered by either sea-borne aircraft or aircraft operating from land bases. The object of air attack will be generally similar to that of an attack by naval forces. Such attacks may also be employed on account of moral and disorganizing effect.

iii. *Land attack.*—A land attack may consist of operations on a large scale with a view to the capture and retention of a port or by raiding attacks directed against important vulnerable points with a view to their destruction or neutralization.

77. Probable forms of sea attack

These may be summarized as follows :—

i. Long-range bombardment.
ii. Blocking attack and attack by boomsmashers.
iii. Attack by destroyers and motor torpedo boats.
iv. Attack by submarines and minelayers.

78. Long-range bombardments from the sea

1. Long-range bombardments may be either :—

i. Area bombardments, against towns, dockyards, harbour works, oil-fuel depots, shipping, etc.
ii. Bombardments of individual defence works.

Such attacks might be made by capital ships (in exceptional cases), obsolete armoured ships, specially built craft, cruisers

or raiders. The ranges at which they might be undertaken are from 15,000 to 35,000 yards and observation of fire, at extreme ranges, unless topographical conditions are very favourable, would only be possible with the assistance of aircraft.

2. Area bombardments are unlikely to effect any vital damage to important objects, such as dock gates, etc., which are comparatively small; the expenditure of ammunition required to give a reasonable chance of hitting them by this means would be normally prohibitive, but they may produce considerable moral effect, hamper the use of harbours, make the docking and repair of ships difficult and undermine the morale of the civil personnel.

3. Long-range bombardments of individual works will probably be undertaken only in conjunction with some other form of attack, *e.g.* blocking attack, landing attack, etc., and as part of a general attack on a fortress, with a view to neutralization.

4. It may be assumed that only in exceptional circumstances, *i.e.* when the weather is thick or the shore guns are definitely outranged, will a ship anchor or even remain stationary when carrying out a bombardment. Normally, therefore, bombardments will always be made by ships in motion. Further, the latter will change course and speed to increase the difficulty of accurate fire on the part of the shore batteries and to complicate air attack and observation.

5. Smoke screens may also be employed to hide the position of the bombarding vessels from the shore observation posts, and movements within the smoke screen will be difficult to follow even with the aid of air spotters.

6. Such methods, although embarrassing the fire of the defence, must also intensify the difficulty of accurate shooting for the attacking ships. It is therefore considered that long-range bombardments of individual works or batteries will not as a rule be attempted and area bombardments, with the possibility of causing damage and destruction to groups of works, power stations or other objects of military value, are more probable.

7. *Special coast attack vessels.*—Capital vessels forming part of sea-going fleets are not likely to be employed in an attack on coast defences. It is more likely that bombardments will be carried out by armoured ships which are obsolete or otherwise unfit for fleet action or by specially constructed monitors.

The development of a type of shallow-draught heavy-gun carrier, on the lines of the monitors used off the Belgian coast

during the Great War, would obviate several of the disadvantages under which vessels intended for fleet action labour when engaged against coast defences, and this probability must be taken into account when the scale and design of coast defences are considered. As monitors are not intended to fight other ships, their design can be directed solely to their primary object, namely the bombardment of land targets; they can carry high-angle fire guns and use the type of projectile most suitable for their purpose. Monitors are usually designed to carry one battery only of large calibre guns. They are practically unarmoured and their light draught enables them to use shallow waters which would not admit of the use of heavier craft, and also gives them a certain degree of immunity from attack by submarines. They are capable of carrying a greater supply of ammunition for their armament than capital ships. On the other hand, they require to be protected against hostile vessels by fighting ships of their own fleet, while the smaller number of guns carried by them militates against their chances of obtaining hits on any small target.

79. Attack by blockships and boomsmashers

Attack by blockship is likely to be made only when the breadth of the entrance or the channel leading to a port is sufficiently narrow to enable it to be blocked by one or at most two ships. It is probable that attack of this nature will take place just before or immediately after the outbreak of war as part of a more general attack in order that the defensive organization may be fully engaged, thus enabling the blockship to reach her position without interference and under cover of night or thick weather. Ships of any kind may be employed as blockships, such as old battleships or vessels specially prepared to enable them to keep afloat under gunfire until the desired position for blocking is reached, but which will be difficult to remove when sunk. Submarines may also be utilized. If the defensive organization includes any form of boom defence, it is probable that attack by either destroyers, submarines or motor torpedo boats will be preceded by a boomsmashing vessel. Such vessels will be of a similar nature to those employed as blockships.

80. Attack by destroyers and motor torpedo boats

1. Destroyer raids may be made with the object of attacking by torpedo war vessels or merchant shipping in the approaches to a harbour or in the examination anchorage. Attempts may be made at night to run past the shore defences

and attack ships in harbour. Attacks by gunfire may also be made against the batteries and searchlight installations.

2. The development of the motor torpedo boat enables vessels lying within anchorages or harbours to be subjected to close attack by torpedo. One of the latest types has an overall length of 55 feet and a speed of 40 knots, and carries the following equipment: two torpedoes, four depth charges, two anti-aircraft machine guns, two searchlights, smoke screen apparatus and wireless telephone. Such a craft, owing to its high speed and ability to turn quickly, offers a difficult target to gunfire. It is, on the other hand, very vulnerable, as its hull is not normally protected by armour and a hit amidships from the smallest type of shell is likely to cripple it. The probable method of attack would be by a swarm of such craft, in an attempt to run past the inner defences in order to reach their target inside the port. The successful penetration by even one or two of them into the inner waters might result in serious damage to ships in harbour, dock gates, etc.

3. The above forms of attack might be made under cover of a smoke screen laid to blanket the searchlights.

81. Attacks by submarine and minelayers

1. The types of submarine attack may be :—

i. Bombardment at medium or close ranges.
ii. Attack by torpedo on vessels lying in, entering or leaving a port.
iii. Mine-laying in the approaches.

Although action against submarines is primarily the function of naval forces, the air and shore defences may be required to co-operate. Modern submarines are normally equipped with a battery of semi-automatic guns of from 4 to 6-inch calibre. The use of these may prove an effective method of carrying out a bombardment of the inner defences, *e.g.* 6-inch (15 degree) batteries, anti-coastal motor boat equipments and searchlights. The small target presented by such craft and the rapidity with which they can submerge will give them a considerable measure of protection against land guns. It is possible that an improved submarine may carry a long-range gun capable of engaging the primary batteries. Submarines are also active agents for attacking by torpedo vessels entering or leaving port and, where conditions permit, such attempts may be made against ships in harbour or against floating docks or caissons.

2. *Mine-laying.*—This form of attack consists in mining the roads or approaches to a port. Submarines of a certain class carry a number of automatic mines for this purpose.

The extensive laying of mines will be the work of specially constructed mine-layers. Small coasting steamers and trawlers have also been employed in the past on this work, taking advantage of their appearance and normal occupation to camouflage these activities. The actual laying of the mines will usually be done at night or under thick weather conditions.

82. Forms of air attack

The development of aircraft is such that in certain localities the menace to ports and their defences from the air may become greater than that from the sea and that bombardment from the air may supersede that from ships. Air attacks can be delivered by sea-borne aircraft, *i.e.* those carried in aircraft carriers or other vessels, or by aircraft operating from a land base, but in either case the forms of attack may be considered under the following categories :—

i. Bomber attack.
ii. Fighter and torpedo attack.
iii. Other forms of air attack.

83. Bomber attack

1. The objectives of bomber attack on a port will generally be ships in harbour, store depots, oil fuel installations, etc., while the defence works, searchlight installations, wireless stations, observation posts, etc., may be subjected at any time to bombing of a varying degree of intensity. In addition, this form of air attack may be employed on account of its moral and disorganizing effect on the civilian population generally or as a means of interfering with the repair facilities of a dockyard essential to naval forces.

2. Attacks by bombers may be expected at any time after the declaration of war, either as part of a general attack on the fortress or in the nature of an independent raid. Even if the defenders possess local air superiority, it will be difficult to prevent bombing raids, especially those made under cover of darkness, with engines shut off, or from behind cloud formations, thus giving the defenders little or no warning.

84. Fighter and torpedo attack

1. Fighter aircraft may be employed in low-flying attacks against targets specially vulnerable to machine gun and light bomber attacks, *e.g.* personnel manning coast defence armament, anti-aircraft guns and searchlights, power stations, workshops, etc.

2. The development of torpedo aircraft offers a method by which, if topographical conditions permit, attempts may be made to attack vessels lying at anchor within a port. Modern aircraft carriers are equipped with machines which can carry a torpedo or equivalent weight in bombs for such action against shipping.

85. Other forms of air attack

1. Attack by airships. The airship has a much wider radius of action and a larger bomb-carrying capacity than the aeroplane. It suffers, however, from extreme vulnerability to attack, especially by aeroplane. On the other hand it is possible that an airship arriving by night from a distant base, moving at a great height with engines cut off, might be able to carry out a surprise and very devastating bombing attack on an important dockyard.

2. When the terrain permits, troop-carrying aircraft may be employed to land small parties, under cover of darkness, with the intention of carrying out a destructive raid on an installation of military value.

3. Gas attack by specially fitted machines is a possible form of enemy air activity, since such machines are used in many places for the destruction of locusts, spraying cotton fields, etc. The gas is released in liquid form from containers and volatilizes subsequently from the ground which has been sprayed. Bombing with gas-bombs is also a possible method of gas attack from the air.

86. Forms of land attack

1. Attacks may take the form of :—

- i. Operations on a large scale with a view to the capture and retention of a port :—
  - (*a*) By a force advancing from a land frontier.
  - (*b*) By a landing in force beyond the range of the fixed defences.
  - (*c*) By a landing in force within the range of the fixed defences.
- ii. Raids to destroy isolated gun positions or special objectives, such as dock gates, oil fuel depots, etc.

2. Operations to capture a port by land attack will most probably be based on a landing executed outside the fortress area and not under the fire of its guns or by an advance across a land frontier. Such an attempt would be undertaken in considerable strength and pushed forward with the utmost rapidity, in order to achieve its object before the

arrival of the relieving fleet or squadron. The success of these operations must largely depend on the completeness of the neutralization of the defending air forces.

Alternatively such an operation might form a portion of the operations in the main theatre of war and defence against it would be undertaken by the defendant's army.

3. Under certain conditions, when a decision must be reached within a limited period of time, the more normal method of attack as described in para. 2, above, may be replaced by a landing within the range of the fixed defences and directed at the most vulnerable areas within the fortress. Such an operation, known as a *coup de main*, is a highly hazardous form of attack. Since its success is largely dependent on the degree of surprise obtained, it is more likely to be carried out in the early stages of a campaign before the defence is fully organized or as the first act of war.

4. Raids may be made by small parties landed from war or merchant ships or from aircraft and will very possibly be assisted by local agents within the fortress. Their object would be to damage or destroy vulnerable points such as isolated gun positions, wireless stations, water supplies, cable landings, etc., or to create a diversion in conjunction with other operations. Such attacks, which would usually be made at night and as part of a *coup de main*, are specially to be guarded against in the early days of hostilities.

87. Gas attack

1. Gas may be used in the form of gas clouds or gas projectiles.

2. Gas-cloud attacks require suitable wind conditions. They might be delivered by means of :—

i. Gas floats, carried on small vessels and laid under cover of darkness in suitable positions where they would emit a stream of gas for a long period.

ii. Special gas craft, capable of moving at high speed, which would create a gas cloud of considerable volume in a short time.

iii. Submarines, which could be specially fitted as gas vessels and, where the hydrographical conditions are favourable, might be able to deliver a cloud at closer range than a surface vessel.

iv. Aeroplanes fitted with special gas containers (Sec. **85**, 3).

3. Gas shells may be used by bombarding vessels as a means of silencing the artillery of the defence during the execution of an attack.

CHAPTER XI

FORMS OF DEFENCE AND THEIR ORGANIZATION

88. Introductory

1. It will be seen from the previous chapter that the forms of attack which can be undertaken against a defended port are numerous and varied in character and capable of being developed from sea, land and air, either separately or in combination, so that the defence must be developed in all three elements. This entails the closest combination and co-operation between the Navy, Army and Air Force.

2. The responsibility of the various Services is as follows :—

i. The Navy is responsible for the extended defence, *i.e.* observation and defence on sea, which include torpedo-craft, submarines, patrol boats, etc., and for the provision of sea obstructions, temporary or permanent, such as mines, nets, booms, etc. The Navy also controls all shipping entering or leaving the port and usually maintains the floating portion of the examination service.

ii. The Army is responsible for all artillery defence (including the examination battery), for searchlights, for anti-aircraft defence, for defence against land attack, whether sea-borne or across a frontier, and for internal security.

iii. The Air Force is responsible for distant air reconnaissance, for torpedo and bomb attacks on enemy vessels, for attacks on enemy aircraft and for close reconnaissance and co-operation with the coast and anti-aircraft artillery.

3. The co-ordination of the three Services in the defence (including defence against gas) of a fortress (except at dockyard ports in Great Britain) is vested in war in an officer designated the fortress commander.

4. The scale of the defensive organization to be adopted for a defended port will depend on the probable nature, scale and duration of overseas attack. This is a question of policy which will be decided by political, geographical and financial considerations.

89. Main defensive armament

1. The armament of a fortress is divided into three main categories :—

i. Anti-ship.
ii. Anti-aircraft.
iii. Movable.

2. *The anti-ship armament* is sub-divided as follows :—

i. *Counter-bombardment guns*, viz. heavy (above 9·2 inch) and medium (9·2 inch) guns, primarily intended to engage, at long range, ships attempting to bombard the fortress. Medium guns may also be used against blockers and boomsmashers ; if required for this purpose, they are provided with defence electric lights.

ii. *Close defence guns* (guns of 6-inch and 4·7-inch calibres).—These are chiefly intended to engage vessels attacking at short range, endeavouring to enter the harbour in order to attack vessels in it, block the entrance of the harbour or smash the boom defence. They may also be employed for firing landwards in the defence of beaches or prepared defensive positions. Since the type of attack for which these defence guns are provided is normally carried out under cover of darkness, batteries sited for close defence are provided with defence electric lights. Certain 6-inch guns on high angle mountings may also be used as additional counter-bombardment guns.

iii. *Anti-motor torpedo boat guns* (12-pr. or 6-pr. guns). —These are intended to engage motor torpedo boats or other light vessels endeavouring to enter the harbour in order to attack vessels at anchor, or such vulnerable points as dock gates, by torpedo. They are normally provided with defence electric lights to enable them to engage their targets at night.

iv. *Defence electric lights*.—These are classified as follows :

(*a*) *Observation lights*.—Concentrated movable beams to detect the approach of hostile craft.

(*b*) *Fighting lights*.—Concentrated movable beams which illuminate targets to be engaged by the close defence guns.

(*c*) *Illuminated area lights*.—Dispersed fixed beams providing an illuminated area covered by the anti-motor torpedo boat armament.

The command, organization, siting and operation of these defence electric lights are dealt with in Chapter XII.

3. *The anti-aircraft armament* consists of :—

Guns specially designed for engaging aircraft and sited for the general anti-aircraft defence of the fortress, in co-operation with the necessary anti-aircraft searchlights.

Light automatic weapons, machine guns, or small calibre equipments of special design, sited primarily for defending certain specific points or limited areas against low-flying attack.

4. The *movable armament* consists of medium and field artillery equipments and is intended to assist the defence by:—

i. Action on land fronts.
ii. Action against attempted landings.
iii. Action against an enemy who has forced a landing.

90. Passive methods of defence

1. Although the gun is the principal weapon of coast defence, there are certain accessories without which no defensive organization would be complete. Booms and other floating or fixed obstructions to deny the passage of waterways to an attacker have been used in conjunction with artillery defences from early times. They perform for harbour defences the same functions as wire entanglements perform for land defences, viz. that of arresting the progress of the attackers and delaying them under the close fire of the defenders.

2. Submarine mines are particularly effective, since they combine the functions of a weapon with that of an obstacle. No vessel can venture into an area where mines are believed to exist until a passage has been cleared by the slow process of sweeping with small vessels. In combination with guns and with searchlights to prevent sweeping operations by night, submarine mines are a valuable contribution to coast defence.

3. Two varieties of mines are used : —

i. Controlled.
ii. Contact.

The former are laid in lines on the bottom of the fairway, being connected by cable to the minefield control station ashore. The operator fires the line of mines by putting through a firing battery.

Contact or uncontrolled mines are attached by a mooring line to a sinker. The mine is kept at a constant depth through the action of a hydrostatic balance. The mine explodes when hit. This type of mine can be usefully employed in defence to deny the use of anchorages, etc., which might be of service to the enemy.

91. Defence against long-range bombardment

1. Attempts to destroy or damage important installations, establishments, defence works, etc., in a fortress may be made by gunfire from hostile ships, either with or without an attempt at landing (*see* Sec. **78**).

If this type of attack is considered possible, the defensive organization should include some long-range counter-bombardment armament capable of driving off hostile vessels attempting to bombard the fortress. The calibre and number of such weapons provided is dependent on the class and number of hostile ships which it is anticipated may be employed in the form of attack.

2. Such counter-bombardment armament should be sited as far in advance of the area or areas which it is desired to protect as topographical conditions permit, so that the enemy vessels are forced to close within short ranges of the defensive batteries in order to bombard their probable objectives.

Heavy guns, while sited to command all water areas from which hostile vessels could carry out a bombardment, even at extreme ranges, should, wherever possible, be concealed from view from the sea. Concealment of flash from an observer at sea should be arranged when possible.

Medium guns, since they are often required to assist the close defence batteries in dealing with blockship, etc., attack, are normally sited on a forward slope so as to command as widely extended a view of the water area within their range as possible. Medium batteries will therefore usually be visible from the sea. They should, however, be sited in such a way that, when viewed from seaward, they are well camouflaged and are not on a skyline.

3. Heavy and medium guns should normally be grouped in batteries of two or preferably three guns, so as to allow of salvo firing.

4. Owing to topographical and climatic conditions or the use of smoke by hostile vessels, observation of fire from ground observation posts may not always be possible; special aircraft may therefore be required to spot for the counter-bombardment batteries, indicating the position and movements of the bombarding vessels as well as the fall of shot.

92. Defence against blocking attack and attack by boomsmashers and destroyers

1. This form of attack is only likely to be attempted when a considerable degree of surprise can be obtained. It will

thus usually be carried out by night or under cover of thick weather and smoke.

At night the amount of warning available is limited to reports from patrol craft and look-outs equipped with night glasses, and by the range of the defence electric lights and in the case of destroyers the speed of attack may be considerable, the close defence armament provided to counter these forms of attack should be capable of a rapid rate of fire and be of a calibre which will have adequate stopping effect on the probable form of targets, the number of hits required being thus reduced to a minimum.

6-inch guns fulfil these conditions and are thus provided, together with the necessary defence electric lights, known as fighting lights, to cover the entrance to the anchorages at defended ports.

The number of guns and defence electric lights required is dependent on the scale of attack and the importance of the objective to be protected.

2. Close defence armament should be sited in depth and as far in advance of the area to be protected as topographical conditions permit, so that the blockships or boomsmashers come under fire for as long as possible.

Where possible, observation lights should be sited well in advance of the close defence batteries and their fighting lights, so that early warning of attack may be obtained.

3. Advantage should be taken of the presence of any medium counter-bombardment batteries sited in the area for which the close defence batteries are provided to increase the power and depth of the defence. Such counter-bombardment batteries should, if possible, be provided with their own fighting lights.

4. Close defence guns should be grouped in batteries of two or three guns. Guns forming a battery will be mounted sufficiently high to enable auto-sights to be used up to the limit of the range of the fighting lights allotted to the battery.

93. The examination service

1. Since hostile vessels may be disguised as ordinary merchant ships engaged on the normal task of carrying merchandise and under such a guise an attempt may be made to sink them in the entrances of a harbour or to blow them up in the vicinity of dock gates or other vulnerable points, some system of examining vessels before they enter a port is necessary in time of war.

2. The examination service consists of the following :—

i. An examination steamer, which is responsible for determining whether a merchant ship is friendly or hostile. The examination steamer meets incoming ships in the approaches to a harbour, when it may be able to decide that a ship is friendly ; in doubtful cases the ship is directed to the examination anchorage.

ii. The examination anchorage, where more detailed examination can be carried out. This anchorage should be to seaward of and within close range of the guns and lights of a battery.

iii. The examination battery, which will normally cover the examination steamer both in the approaches to a harbour and in the examination anchorage. In certain cases, however, two batteries will be required. In these cases the battery covering the examination steamer in the approaches to the harbour is called the examination battery and the battery covering the examination anchorage is called the supporting battery. The examination battery will be in continual signal communication with the examination steamer. The supporting battery may be in direct touch with the examination steamer or may receive information about incoming shipping from the examination battery over the R.A. command lines.

94. Defence against motor torpedo boat attack

1. Motor torpedo boats are lightly built, small, handy and fast craft. As they are comparatively cheap, it is probable that a large number will be used in an attack in the hope that some at least will escape the fire of the defence and be able to enter the anchorage.

Since speed and surprise is the essence of the plan of attack, it is probable that such attacks will only be made at night.

2. 6-inch and 4·7-inch guns are not suited to engage such targets, as their rate of fire is too slow. Special anti-motor torpedo boat (A.M.T.B.) equipments firing a light shell (6-pr. or 12-pr.) with a high rate of fire and ability to switch rapidly from one target to another are therefore provided at all ports which are considered liable to this form of attack. They should be provided with their own lights in the form of an illuminated area or dispersed movable beams, in order to ensure that no target escapes observation.

3. Anti-motor torpedo boat defences should be sited in depth and as far in advance of the objective as topographical

conditions permit. Where depth is unobtainable, as in the case of a straight coast line and a built out harbour, a larger number of defensive weapons should be emplaced and an anti-motor torpedo boat boom provided.

95. Defence against submarines and minelayers

1. The first line of defence against the activities of submarines is an efficient submarine patrol, including aircraft, which will locate and deal with these craft before they can reach the approaches of the port.

2. Minefields laid in the approaches will prevent or deter submarines from making attacks on shipping in the outer anchorage and suitably protected anti-submarine booms will prove an effective barrier to their entrance into the inner harbour. Long-range torpedo attacks can be frustrated by the use of anti-torpedo baffles.

3. Since, however, mines and baffles may not be available or hydrographical conditions may prevent their use, it may be necessary to rely solely on the guns and lights of the fixed defences to deal with this form of attack.

Submarines have the great advantage of being able to approach their objective unseen and thus offer no target to the gun until they break surface. Only by great vigilance on the part of the observers and by quick action by the guns (and lights if at night) can such attack be repulsed. A submarine awash offers a very vulnerable target to gun fire, as her surface speed is comparatively slow. In calm bright weather the aircraft of the defence will be of considerable assistance in detecting the approach of a submarine.

4. Minelayers will probably operate during darkness or when visibility is poor. They will be dealt with by the medium and close defence guns on the same lines as described for the action against blocking attack.

It may be that innocent looking merchant vessels, trawlers, etc., will be used for this form of attack. Vigilance and activity on the part of the examination service will be necessary to prevent such craft carrying out their task without being brought to account by the shore guns.

96. Defence against air attack

1. The active means of anti-aircraft defence in a coast fortress are aircraft, anti-aircraft artillery and small arms, supplemented by anti-aircraft searchlights and sound-locators. The passive means are aerial obstacles, concealment and protective dispositions. All the above must be co-ordinated and controlled in order to obtain the best results against air attack.

2. *Bomber aircraft attack.*—An active defence by fighter aircraft, whereby enemy bombers can be driven off or destroyed before they reach their objective, is the best safeguard against this form of attack. Fighter aircraft can, however, be employed for this task only when there is sufficient depth in front of the vulnerable area to enable :—

i. observation posts to be established at such a distance from the vulnerable area that warning of attack can be obtained in sufficient time to enable the fighters to take off and gain the necessary height for aerial combat ;

ii. a fighting zone of at least 15 miles in depth which can be illuminated at night to be established.

Owing to the proximity of defended ports to the coast line these two requirements can seldom be attained and thus conditions normally militate against the successful use of fighter aircraft as a defensive weapon. Since it is less dependent on the length of warning, the anti-aircraft gun and searchlight must therefore be regarded as the main defence. Apart from their destructive powers anti-aircraft guns will have the effect of making aircraft change course frequently, thus affecting the accuracy of their bombing.

3. *Low-flying air attack.*—This may be directed against ships at anchor or at objects of military importance in the fortress. Although the anti-aircraft guns of the defences would do their part in engaging any enemy aircraft approaching over the land, it is the duty of armed ships to protect themselves against such attack. All vulnerable points in the fortress area, *e.g.* defence works, anti-aircraft searchlights, power stations, ammunition dumps, etc., should be provided with machine guns or light automatics to deal with low-flying attack. The aircraft carrying it out may avoid the air patrols and anti-aircraft guns by making use of mist or clouds, and so the installation of special small-bore armament at threatened points is essential.

4. In cases where topographical conditions permit, raids by troop-carrying planes may be attempted. Such raids will be dealt with by the anti-aircraft defences in the first instance. Sentries should be posted at likely landing places connected by telephone to fortress headquarters, in order to permit of mobile reserves being despatched to a threatened point. All defence works should be provided with strong wire obstacles and should have their own means of local defence.

5. Defence against gas attack from the air would be treated as for bomber attack (*see* paragraph 2, above) and the anti-gas precautions indicated in Sec. **98** would be put into operation. Installations which are vital to the successful functioning of

the defences should, however, be rendered gas proof and arrangements made to clear gas from those installations which cannot be gas proofed, as rapidly as possible after the cessation of an attack of this nature.

6. Passive defence measures include :—

i. Adequate protection of all vulnerable points, such as oil stores, ammunition depots, essential communications, etc., against air attack by providing them with bomb-proof cover. This normally necessitates underground construction or the dispersion of the vulnerable stores or establishments over a large area, thus not only minimizing the effect of direct hits but making it more difficult for the attacker to select his target.

ii. Concealment.—Although it is a matter of difficulty to conceal the main features of a fortress, judicious camouflage will help to merge a battery or other vulnerable point into its surroundings. The construction of dummy works will also provide a considerable measure of concealment as well as tending to confuse the attacker.

iii. The provision of an air raids precaution organization. This organization should provide passive defensive measures for both the garrison and the civil population of a fortress.

97. Defence against land attack

1. *A force advancing from a land frontier.*—If the fortress is being closely invested from the sea, it will usually be impracticable to land reinforcements to march inland and meet this form of attack. The mobile troops of the garrison, therefore, assisted by all available aircraft, will do their best to delay and impede the advance. But ultimately, if the enemy is strong enough, the garrison will be forced back upon the fortress and will have to occupy previously prepared defensive positions covering the fortress from the landward side. Such defensive positions will be organized and held according to the principles laid down in Field Service Regulations, Vol. II, for the occupation of a defensive position. The actual defence work will be of the nature described in Part I of this manual.

2. *Landings in force outside the range of the fixed defences.*—An open bay with a sandy beach and especially one not exposed to prevailing winds and storms is likely to be chosen by an enemy for a landing. Roads leading to the fortress or to tactical features, which can be occupied as a preliminary to the capture of the fortress, add to its advantages from the

enemy's point of view. The place chosen for the disembarkation will usually be at such distance from the port as to be out of range of the counter-bombardment guns of the fixed defences. If the enemy once succeeds in occupying high ground commanding the land approaches to the beach or beaches and gains sufficient air superiority, he will be in a position to disembark his main striking force, heavy guns and stores. It is thus very desirable that he shall be prevented from obtaining a footing on land. Therefore, if the fortress has a mobile force of sufficient strength at its disposal, it should be despatched at once to the threatened point with the object of preventing the enemy from establishing himself on a covering position and all available aircraft should be used to harass and delay the landing operations. Should, however, the enemy obtain a footing ashore, the situation will eventually develop into one similar to that described in Sec. **99**, 1, and the issue will be fought out on the defensive lines covering the fortress.

3. *A coup de main or landing in force within the range of the fixed defences.*—For the prevention of landings in the immediate vicinity of a fortress the essentials are a good system of reconnaissance, coast watchers and communications so as to give early warning of such intention, and a suitably placed mobile reserve to deal quickly with the situation. The enemy should be prevented from gaining a footing on shore. Local beach defences should therefore be provided at places favourable to this form of enterprise. These consist of machine gun, light machine gun and rifle section posts covering the foreshore, assisted, where necessary, by beach guns and some form of beach illuminations. Reserves of infantry for immediate counter-attack are also provided. Strong wire entanglements should be erected near high-water mark and obstructions placed in the water to hold up the boats carrying the landing party. Beach illumination may be provided by means of beach searchlights, beach flares or parachute flares fired from mortars or dropped from aircraft.

4. *Raids.*—Since the object of raids is the destruction or neutralization of some vital portion of the defensive organization, the raiding party will in all probability be landed in close vicinity to its objective and thus within the area covered by the fixed defences. Defences as described in para. 3, above, will provide security against this form of attack. Since, however, such raids may be assisted by local agents carrying out sabotage and small parties landing at unlikely places may escape the vigilance of the beach defences, it is essential that all installations which are of vital importance to the defences should be provided with some form of barbed wire protection and a sufficient armed guard to hold off the raiding party until assistance can be obtained from the general reserve.

98. Defence against gas

1. The general defensive measures against gas attack are stated in Sec. **117,** 1 and 2.

2. Anti-gas precautions against gas clouds released from the sea by means of floats or specially prepared vessels will be of a similar nature. The first line of defence will be the respirator and the second the provision of adequate gas-proof shelters. This form of gas attack will, however, probably be made at night ; gas sentries provided with means of early detection of lethal gas should therefore be stationed at all installations which are open to this form of attack.

3. Protective anti-gas measures and precautions for civilians will be carried out under arrangements as stated in Sec. **22,** 4.

99. General organization of the defence of a fortress

1. The military portion of the defensive organization may, (Sec. **90,** 2, ii) include some or all of the following :—

- i. Fixed defensive armament, including batteries, defence electric lights and other permanent works.
- ii. Anti-aircraft defences, including guns and searchlights.
- iii. A mobile garrison, including infantry, artillery, engineer and ancillary services.

2. The fixed defences installed for the defence of a fortress are normally organized into fire commands ; a fortress may be organized into one or more fire commands according to topographical and tactical considerations. Each fire command includes all batteries and defence electric lights that cover the area of water included in the fire command and it is controlled by an artillery officer styled the fire commander. This officer is responsible to the fortress commander for the fighting of the fire command.

3. The anti-aircraft defences allotted to a fortress are normally organized under a separate commander known as the anti-aircraft defence commander. This officer is responsible to the fortress commander for all matters concerning air defence, including any passive defence measures that may have to be taken. His headquarters should be contiguous to those of the fortress commander.

4. The mobile garrison is allotted to the defence of beaches, to defensive lines or to form a mobile force as circumstances demand.

CHAPTER XII

FIXED DEFENCE WORKS AND ORGANIZATION

100. Types of emplacements for fixed guns

1. Fixed emplacements are normally of the open type, constructed of concrete, protection for the gun detachment being provided by the shield which forms part of the gun mounting.

2. The design of emplacement varies with the type of gun and mounting. The essential point is that the gun should have a stable support on a fixed platform.

3. The accurate levelling of the mounting is of vital importance, as the effect of any tilt varies as the mounting is traversed. This necessitates care and accuracy in laying the foundation for the pedestal or its equivalent, although mountings are provided with means for compensating for small errors in level.

101. Concealment of gun positions

1. Guns for indirect fire can generally be sited so as to be concealed from view from the sea, while in the case of guns mounted for direct fire it will generally be possible, by judicial selection of sites and by colouring guns and their mountings, emplacements and aprons, to make them very difficult to distinguish from their background and surroundings at any but short ranges. The great desideratum is a good background.

2. Invisibility from the air is less easily obtained and no really efficacious means has yet been discovered. The only way to secure it is by overhead camouflage on the lines described in Sec. **41**, which would not ordinarily be provided before the outbreak of war and which is facilitated by breaking up the plan of the battery.

102. Requirements of a battery

The following points should be adhered to in the design and construction of a battery :—

i. The general lay-out should be as irregular as is feasible, in order to give as little aid as possible to a hostile spotting aeroplane. On certain sites it may be advisable to cover parts of the battery area with trees 20 to 30 yards apart.

ii. The site selected should not be in close proximity to buildings which may act as aiming points for hostile fire direction.

iii. The battery enclosure should be made secure against surprise attack and against the possibility of sabotage at all times (Sec. **97**, 4).

iv. The battery should have adequate accommodation for ammunition, rations, accessories, stores and personnel in addition to a well protected water supply, so that the work may be self-contained in every particular and capable of protracted defence.

v. Emplacements should be kept as low and inconspicuous as possible, the guns being in pits with the trunnion-level a little above ground level.

vi. Shelters, magazines, stores, etc., may be provided with appliances for gas decontamination. This subject is dealt with in Sec. **22**.

103. Types of batteries and emplacements

1. *Counter-bombardment batteries.*—The emplacements for 15-inch and 12-inch guns are usually spaced at such intervals that each emplacement has to be self-contained in its ammunition supply, power and war accommodation. Heavy guns may be emplaced in two ways, either in open emplacements as for the 9·2-inch medium gun described hereafter, or in pits designed to take a turret type of mounting. The advantage of the latter mounting is its relative invulnerability.

A 9·2-inch battery consists of either two or three guns, each having its own magazine with shell-proof protection.

Emplacements are of the open or barbette pattern, the gun and crew being protected by an armoured shield.

2. *Close defence batteries.*—

i. 4·7-inch and 6-inch guns are usually sited in pairs with magazine in a convenient position.

ii. 12-prs. are usually arranged in pairs, the guns being sited sufficiently close together to enable an officer to control the section by voice.

6-prs. may be sited singly, or in pairs as for the 12-pr.

Ammunition will normally be supplied from one central magazine between or in rear of the guns.

104. Ammunition supply

1. The storage and supply of the equipment ammunition for a coast defence battery has to be considered under two categories :—

i. That required for the immediate service of the gun.

ii. That stored in the magazine to supplement (i).

2. Every gun must have an adequate supply close at hand, so that fire can be opened without delay and continued until further shell and cartridges are available from the magazine.

i. This ammunition is usually stored in cartridge and shell recesses built into the wall of the emplacement, whence it can be rapidly transferred to the gun platform.

ii. Although the service from the magazine to the gun floor can be carried out by hand or by hand power for small calibre ammunition, power operated hoists are generally provided in 6-inch batteries; for heavier ammunition mechanical methods are essential, with an alternative method for hand working in case of break-down. Power will usually be required in the case of 6-pr. anti-motor torpedo boat equipments owing to the high rate of delivery required.

105. Power supply to batteries

Power is required in batteries for electric lighting, ventilation and power-operated ammunition hoists, and in the case of 9·2-inch and 15-inch guns for the high pressure oil system operating the mountings and for the compressed air system.

Where power requirements are small, a supply of electricity will normally be taken from a near-by D.E.L. engine room, but in certain cases a small auxiliary generating set may be installed in or near the battery.

In 9·2-inch 35 degree batteries a central underground engine room, equipped with oil engine driven generating sets, supplies power to pump chambers at the guns. These chambers contain electrically driven oil pumps and air compressors.

Each 15-inch gun is provided with its own engine room with an oil engine driven pump for the high pressure oil supply to the mounting, and electrical generating machinery for auxiliary services.

These underground engine rooms require special arrangements for water and oil cooling and for engine room ventilation. Alternative exits are provided for hot air and exhaust gases from the engines, either of which is adequate to maintain efficient operation of the plant should the other be blocked or damaged. The gas proofing of these engine rooms is not provided for.

A typical 9·2-inch 35 degree battery engine room is illustrated in Plate **29**.

106. Accommodation for personnel

Shelters are required for all gun detachments on duty. They should be situated in the immediate vicinity of the guns.

Splinter-proof shelters at ground level are provided in the typical design of 9·2-inch and 6-inch batteries. The advantage of this type is quick access to the gun. Relief detachments will normally be located in the war accommodation which is constructed in the vicinity of the battery.

107. Command posts and posts for range-finding instruments

1. Observation posts are normally constructed in concrete; they must be sited to afford a view over the whole of the water area covered by the guns which they serve, while the dimensions of the post must permit of the instruments covering this area. The observation post must be provided with steel shutters having strong internal fastenings and an entrance door which will ensure the security of the instruments and charts within.

2. The battery observation post should be sited so that the battery commander can see clearly the whole of the water area which the guns cover and can observe their fire. In the case of battery observation posts for close defence batteries, where efficient supervision and easy transmission of orders are the ruling factors, proximity to his sections and a good view of the battery are essential. In the selection of a site for any observation post consideration must be given to the fact that dust and smoke caused by the discharge of the guns should not obscure the target. For these reasons the main day battery observation post should normally be well to a flank and not less than 100 yards from the nearest gun.

3. It will often be desirable to provide an alternative battery observation post on the other flank of the battery, from which the battery commander or an observation officer can direct the fire of the battery.

4. A fire commander's post similarly requires to have a clear view of the whole of the water area which his guns cover, combined with as extensive a view as possible over water by which vessels of any type may approach the defences. A high site is preferable, so as to give an extended view seawards and accuracy in the use of the range-finding instruments. The post should be large enough to accommodate the fire commander's staff, consisting of one or more assistants, telephone operators, orderlies and signallers.

5. All observation posts should be camouflaged, so as not to be identifiable from sea or air. It may sometimes be possible to do this by putting them inside civil buildings or making them resemble such buildings in outward appearance. If nothing else is possible, the ordinary camouflage methods, described in Sec. **34**, should be adopted.

108. Tide-gauges and datum posts

1. Some method for determining the exact height of the instrument above sea level is required in connection with depression range-finding and position finding instruments.

Such information is obtained by readings from a tide-gauge or by setting the instrument on the water line of a datum post or moored buoy.

Siting of these is governed by the following considerations :

i. The avoidance of obstructions in a fairway or the interference with the navigation of small craft or with fishing interests.

ii. The avoidance of a position in a re-entrant or elsewhere, where the water may bank up and give a fictitious level.

iii. The avoidance of a reef, etc., swept by heavy seas.

A datum post or moored buoy must be located at the most convenient range, according to the nature of the gun served by the instrument and the height of the latter above ordnance datum.

In all cases the sites proposed for datum posts should be jointly selected by the R.A. and R.E.

2. *Tide-gauges.*—When tide-gauges give reliable data, they should be used in preference to datum posts. They should be fixed in a position comparatively near and easily visible from the observation post or guns to enable them to be used in hazy weather, when the more distant datum posts are obscured. For night work they must be capable of illumination by a defence electric light. Tide-gauges should stand up vertically and have a broad, clearly marked face. Painting graduations is unsatisfactory, as the marks soon become indistinct and have to be repainted, whereas an enamelled plate will only require an occasional wipe-down.

Two descriptions of plates are manufactured for the W.D. viz. :—

1 foot 6 inches, for use up to 2,000 yards.
2 feet 9 inches, for use beyond 2,000 yards.

The markings and dimensions are as shown in Plate **28**. The plate containing the zero line is 8 feet long, all others 4 feet long, and all are provided with holes for fastenings. Fixing :— The zero of the scale must be fixed accurately at the mean sea level of the point at which it is situated. (There may be a small local variation compared with ordnance datum.) A substantial timber backing is required. Metal (not iron) fastenings should be used. Brass bolts, with lead washers against the enamel, are better than screws. The plate should

be rigidly fixed to the backing to prevent vibration. Care should be taken not to crack or chip the enamel, as rust will attack the plate and flake off the enamel. A suggested method of fixing to a wall is shown in Plate **28**. When an existing support to which a tide-gauge is to be affixed is inclined, such as a quay wall with a batter, the zero of the gauge should be correctly set and the error of height due to the inclination compensated by leaving a gap between each length, as shown below :—

5 degrees	inclination	from vertical	gap	=0·18 inch.
10	,,	,,	,,	=0·73 ,,
15	,,	,,	,,	=1·7 ,,

If the inclination exceeds 15 degrees, the plates should not be used.

3. *Datum posts.*—Two datum posts should be available for each instrument. The face of the post should be approximately vertical and its breadth at least six inches for every 1,000 yards of range. It may be constructed as a single pile or in the form of a pyramid made of any suitable material, *e.g.* of concrete, timber, masonry or steel. Often the pile of a pier, the end of a jetty or an existing navigation mark or beacon can be used as a datum post. No graduations are required. The best colour is black. Where the rise and fall of tide is so great that the datum cannot conveniently be constructed as a single post, it may take the form of a series of pillars arranged on the arc of a circle having the instrument as its centre.

The following table gives the ranges considered to be the most convenient for long and short range datum-posts respectively :—

Nature of gun served by the instrument	Height of instrument above ordnance datum		
	300 feet	200 feet	100 feet
9·2-inch	8,000 yards	6,000 yards	4,000 yards
	4,000 ,,	4,000 ,,	—
Below 9·2-inch	6,000 ,,	6,000 ,,	4,000 ,,
	4,000 ,,	4,000 ,,	—

4. *Moored buoys.*—These may be used instead of datum posts when local conditions prevent the use of the latter. They should be conical in shape and painted black. Two mooring sinkers or anchors should be used, connected by a chain bridle, the sinkers being laid along the line of sight of the observing instrument. The length of the bridle should be not less than twice the depth of the water at high tide and the buoy should be shackled to the centre of the bridle by a chain equal in length to the mean rise and fall of the tide.

The buoy should be just awash at the top of the tide. This arrangement limits the movement of the buoy and consequent alteration in range.

NOTE.—No work of this nature or in connection with datum posts or tide-gauges should be undertaken without consulting the local navigation authorities.

109. Defence electric lights

1. Defence lights are an indispensable adjunct to the night defence of a coast fortress against attack by sea (Sec. **91**).

2. Observation lights are placed at the outer limit of the defences and are intended, where practicable, to provide a band of light across the entire navigable entrance, so as to ensure that no surface vessel can enter without being illuminated. They are normally provided in pairs, of which one, called the sentry beam, is maintained on a fixed bearing across the channel and the other, called the search beam, is movable and is intended to search over an area outside the sentry beam.

The sentry beam is less fallible than the search beam, as the latter may occasionally pass over an object without detecting it. If, therefore, there is only one light, it should normally be used as a sentry beam. All lights used as sentry beams should be capable of traversing, so that they can be used, if necessary, as fighting lights.

3. The fighting lights for the close defence guns are normally moving concentrated beams which are allotted to serve specific guns or batteries. They are normally sited so as to provide the best illumination for the guns or batteries to which they are allotted. They are provided in pairs, for the following reasons :—

i. In case one is temporarily out of action, *e.g.* changing carbons.
ii. To enable a battery to engage more than one target.
iii. To hold a second target while the leading target is being engaged.

Fighting lights are also required in support of batteries detailed to cover an examination anchorage.

4. Illuminated area lights are used to light up that portion of the defended water area in which it is intended to deal with raid or attacks by light craft and motor torpedo boats. They should be capable of illuminating all water through which such craft can pass, at any state of the tide.

An essential condition in the tactical employment of these

lights is that there shall be effective illumination right across the navigable channel.

Such lights will normally be sited to provide an illuminated area consisting of a group of fixed beams. In certain localities it may be advisable to provide one or more 16-degree dispersed movable beams on the outer flank or flanks of an illuminated area to enable swift moving targets to be picked up as they approach the illuminated area.

Where the zone is too wide to be covered by an illuminated area, reliance will have to be placed on suitably dispersed moving beams.

When there is a boom, the water area immediately in front of it should be illuminated, but the boom itself should be in darkness. It should be possible, however, to light up the boom if required.

5. *Effective range.*—Lights of two categories are provided :—

i. With concentrated beams of about 2 degrees or 3 degrees dispersion.
ii. With beams horizontally dispersed to cover an arc of 16 degrees or over.

The former are used for observation and fighting while the latter are employed for close defence at short ranges.

The effective range of a light is the distance at which the target is sufficiently illuminated to enable the gun to be laid. This depends on many factors, which may be summarized as follows :—

i. Atmospheric conditions.
ii. The texture, colour, size and angle of presentation of the target.
iii. The strength of the electric arc (high current density or low current density).
iv. The degree of dispersion of the beam.
v. The relative position of the lights and observer.
vi. The training of the gunlayer.

The following figures may be taken as a guide for normal effective ranges at home and overseas depending on the visability :—

Size		Nature of beam	H.C.D.	L.C.D.
120 c.m.	...	Concentrated	7,000–2,000 yds.	5,000–2,000 yds.
90 c.m.	...	,,	6,000–2,000 ,,	4,000–1,800 ,,
90 c.m.	...	16° Dispersed	3,000–1,200 ,,	2,000–1,000 ,,
90 c.m.	...	30° ,,	2,000–1,000 ,,	1,300– 700 ,,
90 c.m.	...	45° ,,	1,500– 700 ,,	1,000– 500 ,,

NOTE.—For purposes of observation only, the range of lights is at least 50 per cent. greater than that required to enable guns to maintain an effective fire on the target.

110. Relative position of defence electric lights and batteries

In considering the relative position of gun and lights it must always be remembered that the object of the defence electric light is to enable the gun to be laid on the target. Consequently the selection of a site for a night-firing battery and its lights should not be made without first considering all the electric light possibilities and the siting of both must be properly co-ordinated.

111. Siting of directing station for defence electric lights

Movable defence electric lights are normally directed by remote control switches from a directing station which is normally the electric light officer's post.

The directing station must be so sited that all the water covered by its own lights is under observation and also the water covered by the lights immediately to either flank.

Unless it can be placed at sufficient height above the lights, to enable the switch operator to look down on each beam throughout its length, it should be placed to a flank. It must in any case be higher than the lights which it directs, so as to facilitate control and observation of the further beam.

112. Tactical control of defence electric lights

1. The tactical control of defence electric lights is in the hands of the artillery. The engineers are responsible for the maintenance of the lights in a state of efficiency and for their tactical operation, as required by the artillery commander.

2. The general co-ordination of the lights and guns in a fire command is the duty of the fire commander. He issues instructions for the operation of the lights, including such decentralization of executive command to battery commanders as may be necessary in the case of fighting lights, or of lights which are normally used for observation and which may be allocated to a battery as fighting lights. He normally retains observation lights and illuminated area lights under his direct control. Fighting lights are normally placed under the commander of the battery which they serve.

3. The officer commanding electric lights (O.C.E.L.) acts as technical adviser to the fire commander and is responsible for the tactical and technical efficiency of all electric light personnel and equipment. He issues orders for the control of such lights as are retained directly under the fire commander. The officer commanding electric light's post will adjoin the fire commander's post and must have a clear view over the water illuminated by the lights.

4. The battery commander is responsible for the tactical control of the group of lights allotted to serve his battery, and he issues his instructions to the electric light officer (E.L.O.) in charge of the group. The latter must be with the battery commander in the same battery commander's post, so that he has the same view as that of the battery commander. The procedure outlined above for tactical control of the lights is followed in searching for targets and after fire has been opened.

5. The post from which the lights are actually controlled should, if possible, be in the same building as the battery commander, so that the electric light officer can give his orders direct to the switch operators.

It is essential, however, that the switch operators should be located so that they have the best possible view of their lights. It may happen on occasions, therefore, that the best site for the station from which the lights are controlled is separated from the battery observation post by some distance. In these circumstances the electric light officer will remain with the battery commander and will issue his orders to the switch operators in the directing station by means of telephone with head and breast set.

6. The principles governing the decision as to whether lights are to be exposed or doused are laid down in the appropriate manual. Orders to expose or douse lights will emanate from fortress headquarters and will be passed by the fire commander to the officer commanding electric lights or battery commanders for executive action. When lights are doused, they will normally be switched off and the main engines shut down or run light. As a temporary expedient, lights can be obscured for short periods by closing the emplacement shutter, operating a dousing screen over the front part of the projector, or by turning the beam into the emplacement.

113. Defence electric light communications

The following telephone circuits are normally required :—

i. Direct lines from the officer commanding electric lights to his electric light officers.
ii. From each electric light officer's post to its engine room and emplacements.
iii. When the directing station of fighting lights is removed from the battery observation post, a direct line between the electric light officer's post (adjoining the battery observation post) to the directing station.

NOTE.—Each electric light officer's post or directing station is provided with a concentrator and telephone which enables the N.C.O. in charge to communicate with his engine room and emplacements.

114. Engine rooms for defence electric lights

The current for defence electric lights is normally obtained from generators driven by compression ignition engines, erected in an engine room in the vicinity of the lights. The engine room may be in a shell-proof dug-out, or, failing that, the engine house, cooling arrangements and store should be at least splinter-proof and sited in a well-concealed position.

Underground engine rooms require special arrangements for cooling and ventilation, as described in Sec. **105.** Where the engine room is splinter-proof only and cooling tanks outside would be unduly exposed, radiator cooled sets should be installed in which the radiator is mounted at one end of the set and a fan driven from the engine ejects air through a suitably placed opening in the wall, which must be protected from splinters by a traverse or by iron louvres.

A small auxiliary set will generally be installed in these engine rooms to provide lighting and to meet small power requirements at times when the main sets are not running.

A typical lay-out for an underground defence electric light engine room is shown in Plate **30.**

115. Emplacements for defence electric lights

The projectors of the defence electric lights should be housed in small covered emplacements for protection from weather and for security of fittings, etc., from theft, the opening in the front of the emplacement being provided with steel shutters, generally of rolling or sliding type.

In emplacements liable to sea spray armoured glass windows will be provided.

116. Signal communications in a fortress

1. The signal communications of a coast fortress are comprised in the following main groups :—

i. *Command and administrative telephone system.*—This provides for communication between the following—

Fortress commander.
Sector defence commanders.
Fire commanders.
Infantry commanders.
Engineer commander.
Anti-aircraft defence commander.
Port war signal station.
The various administrative services.

ii. *R.A. fighting communications.*—These consist of telephonic and other means of communication for—

Fire commanders.
Battery commanders.
Section commanders.
Port war signal station together with range-finding communications, etc.

NOTE.—The fire commander is in direct telephone communication with the selected military officer and advanced look-outs.)

iii. *R.E. fighting communications.*—These consist of direct lines between the officer commanding electric lights and his electric light officers and between electric light officers' posts and the emplacements and engine rooms.

iv. *Alarm circuits.*—These are entirely distinct from the telephone system and normally consist of magneto bells operated by generators.

Separate alarm systems are provided whereby :—

(*a*) Batteries, A.M.T.B. gun sections and mine control stations can alarm the fire commander, and the latter can alarm batteries and A.M.T.B. gun sections.

(*b*) Battery commanders can alarm gun floors, war shelters and reserve watch war shelters. (In certain cases gun floors may be provided with a generator to enable a sentry to give the alarm within the battery.)

(*c*) Section commanders of A.M.T.B. guns can alarm all other A.M.T.B. section commanders in the vicinity and also the electric light officer controlling the illuminated area.

Generators and alarm bells will also be installed in certain R.E. posts to provide a more rapid means of communication than the telephone for conveying orders to " expose " or " douse." A simple code system will be used for this purpose.

v. *Anti-aircraft defence lines.*—These consist of direct lines :—

(*a*) From A.A. gun stations to A.A. Defence H.Q. ; A.A. Battery H.Q. are connected to the nearest of these lines.

(*b*) From L. stations to A.A.S.L. Section H.Q.

(*c*) From A.A.S.L. Section H.Q. and visual plotting stations to A.A. Defence H.Q.

In addition direct lines may have to be provided from observer stations to A.A. Defence Headquarters.

These may extend for some miles outside the area enclosed by the fixed defences and may consist in peace largely of overhead lines or unprotected cables which are replaced by buried cables when an emergency arises.

vi. *Communications to mobile defence units.*—These will consist normally of telephone lines, provided where possible from existing spares, in the fortress lay-out, extended as necessary either by special construction or by utilizing civil telephone circuits.

vii. *Lines required by the Royal Navy and Royal Air Force.*—The command signal company or section should co-operate in the provision of these circuits.

2. *Erection and maintenance.*—The responsibility for the provision of all fortress communications rests with the command signal companies or sections. At home, erection and maintenance is either carried out by the personnel of these units or by the General Post Office on behalf of the War Department.

At defended ports abroad, the whole system is normally erected and maintained by command signal companies or sections, assisted as may be found convenient and desirable by the local telephone authorities.

3. *Manning.*—Fortress command and administrative communications are controlled by the senior signal officer of the fortress and exchanges are normally manned by R. Signals personnel.

Artillery fighting and range-finding communications and engineer fighting communications are manned and controlled by the artillery and engineers respectively.

117. Anti-gas measures

1. The primary defence against gas attack is the anti-gas appliance with which every soldier of all arms is personally equipped.

2. The gas proofing of both bomb-proof and splinter-proof installations and shelters may be undertaken in certain circumstances. The methods employed to provide such anti-gas protection are dealt with in some detail in Sec. **22**, referring to permanent land fortifications, and similar measures are applicable in a coast fortress.

3. Protective anti-gas measures, and precautions for civilians will be carried out under the arrangements described in Sec. **22**, 4.

118. Defence of a beach

1. Works intended to oppose a landing will normally be sited with a view to obtaining the best fire effect on the enemy while he is approaching in boats or in the act of landing ; such works should, if possible, be concealed from view from seawards. The system of defence should be one of mutually supporting defended posts or localities, organized in depth.

2. Machine guns and light automatic weapons provide the main defence ; these should be sited low down and in such position as will enable them to cover the approaches with enfilade fire. Concrete emplacements may be provided as part of the peace preparation on beaches which offer easy access to a point of military importance, etc. Suitable types of one- and two-gun emplacements are shown in Plates **11** and **12**. If construction is deferred until the outbreak of war, preparations should be made for the rapid execution of the work when required. This may be done by (i) block construction, or (ii) the use of quick-setting cement. In the former case the blocks should be cast beforehand and kept stored in sets ready for use. In the latter case all the necessary templates should be ready, together with a reserve of cement and aggregate within easy distance of the site.

3. *Obstacles.*—These may be considered under the two categories of (i) tactical, (ii) protective :—

i. Tactical obstacles must be provided both in the water and on the foreshore. The former are intended to break up the boat formation and to cause delay and confusion while the landing parties are trying to reach the beach. These will consist of floating or partially submerged obstructions, *e.g.* baulks of timber wired together, buoyed wire hawsers, etc. In certain tropical waters where lines of fishing stakes exist these may, if practicable, be joined together and entangled with barbed wire, thus forming a very effective and well-camouflaged obstacle. In addition to these, extensive use should be made of barbed wire entanglements to impede the landing troops after they have got out of the boats and are advancing towards the shore. Wooden posts, well-tarred beforehand, are the best for the purpose if the beach is a sandy one, but in dealing with a rocky bottom and foreshore angle iron pickets will be necessary.

ii. A strong and insurmountable obstacle will be necessary round all the defended posts and localities, to prevent a work being rushed should a landing be partly successful. A permanent unclimbable fence

may have to be provided in the case of works constructed in peace, while in other cases a double-apron barbed wire fence will prove effective.

4. The provision of " road-blocking posts " to command the junctions of roads leading from the coast inland is desirable. Some means of blocking the road (knife-rests, etc.) should be provided.

5. Many varieties of foreshore will be met with and the defence arrangements of each will vary accordingly :—

i. *Shingle beaches.*—The danger here is that the beach may shift and cause considerable damage to the defences and obstacles. In this case it may be desirable to establish the defended posts some little distance in rear with an advanced defence of light machine guns on the shingle bank. Obstacles of a portable nature should be made and held in reserve to supplement the fixed obstacles at places most liable to damage by the action of the sea.

ii. *Sand hills.*—Sand drifts are liable to affect the defences in a similar way to the movement of the shingle. On the other hand, sand hills afford valuable cover and concealment. Sites for machine gun emplacements or posts should be carefully selected and places chosen which have a look of permanancy and are well covered with a growth of grass or scrub.

iii. *Marshy shores with sea walls.*—These are flat areas, intersected by dykes, which can be converted into very useful obstacles as a second line defence. Defended localities may be sited in this case at greater distances apart.

iv. *Cliffs.*—No cliff can be assumed to be inaccessible. The main system of defence should consist of a continuous entanglement on the top of the cliff with the defended posts close to it. Some advanced positions on the lower slopes of the cliff may be arranged, giving a good field of fire on to the foreshore and water. Where the cliffs are very high and steep, the defended posts may be placed at the heads of the ravines debouching on the shore and arrangements made for patrolling the line of cliffs.

v. *Town fronts.*—The sea wall or esplanade should be prepared for defence and the obstacles described in para. 4, above, placed in position on the shore. Defended posts should be at the salients and machine guns sited to fire along the front of the wall. The wall itself between posts can be made

into a very formidable obstacle against assault or escalading. Piers should be prepared for demolition by explosives and fire.

119. Illumination of beaches

1. Since a landing will almost always be attempted under cover of darkness, some form of beach lighting is very desirable to give the defender the advantage of being able to see the enemy without being seen. The possible methods are :—

i. Searchlights in fixed positions.
ii. Mobile searchlights.
iii. Flares fired from infantry weapons and beach flares.
iv. Parachute flares dropped from aeroplanes.
v. Star shell.

2. The illumination of a beach by large searchlights of 90-cm. diameter or upwards in fixed emplacements is an effective method, but costly both in equipment and personnel. The latter consideration rules it out for general application when a defended port is surrounded by a large number of possible landing places. This method will therefore probably be confined to the few exceptional cases where an open beach of limited size gives easy access to a point of supreme military importance or to a depot or installation the raiding of which must be avoided at all costs. A pair of 90-cm. projectors with 30-degree dispersed beams will effectively light a beach about 2,000 to 3,000 yards long, one placed on each flank and defiladed on the seaward side against enemy fire.

A supply of small highly mobile lights of say 30-cm. diameter, which are comparatively inexpensive, may be of great value in reserve, whence they can quickly be despatched to any beach threatened by a landing.

3. The mobile searchlight system has the advantage of economizing plant and personnel, since the equipment can be disposed centrally and despatched to any locality where a landing is anticipated or imminent. There is always the danger that the mobile light detachment will not arrive in time, but, where road communications are good and the beaches not too far apart, this system has much to recommend it.

4. The advantage of flares fired from infantry weapons or beach flares is that the means of illumination are in the hands of the fighting troops and can be made use of to suit the needs of the situation. The lighting effect cannot be as good and steady as that provided by searchlights, but it should be effective in preventing surprise. A variety of flares available, viz. : Signal lights which can be fired from a pistol,

parachute flares discharged from a small mortar and incandescent flares burnt in reflectors on the beaches. This form of lighting the beach and water front would be especially valuable in the case of small surprise raids, of which little or no warning would be given.

5. Parachute flares dropped from an aeroplane are very powerful and provide a considerable area of illumination. They are especially useful in the case of landings in force, when they can be dropped above the convoying vessels and light up the whole operation progressively from ship to shore, affording targets to the fixed and mobile armament of the defence. When the landing craft get near the shore, and still more when the attackers leave their boats, there is a danger that the flares will light up both friend and foe, to the disadvantage of the defenders. They should therefore be used for reconnaissance only ; the actual illumination of the beaches to enable the defensive weapons to aim their fire is better carried out by one of the systems described in the preceding paragraphs.

6. Star shells are similar in their properties and tactical employment if less brilliant than parachute flares dropped from aircraft.

120. Land fronts

1. *Organization.*—The defence of the land fronts of a coast fortress will be organized on the principles laid down in Field Service Regulations, Vol. II.

2. *Execution of works.*—Normally time should be available after the outbreak of war to allow of the execution of the necessary earthworks, provided that a detailed defence scheme, with the necessary plans and tables of labour, tools and materials required, has been drawn up in advance. In cases where it is considered necessary to construct a nucleus of the works in anticipation of war, the most suitable form of works will be a system of concrete machine-gun and infantry posts on the lines indicated in Chapters III and IV.

121. Defence schemes

1. Schemes for placing a coast fortress in a state of defence must be designed so as to deal simply and rapidly with two states of preparation :—

i. A precautionary period.
ii. A war period.

2. *Method of compiling.*—Complete defence schemes, both for the precautionary and war periods, will be drawn up in peace and periodically revised in accordance with the regulations and instructions on the subject (see King's Regulations,

1935, paras. 35 to 38, and the special instructions issued from time to time on the preparation of defence schemes).

3. *Fort record book.*—In expansion of the defence scheme are the artillery and engineer defence schemes. The artillery defence scheme for each battery and each fire commander's post is compiled in the form of a fort record book. In addition to information regarding the armament, ammunition supply and other artillery matters, fort record books require engineer information under the following heads :—

i. A detailed plan of the work and its surroundings.

ii. Sufficient details of the construction of the work to enable officers who will be allotted to the command in war to know what further defensive arrangements they may make without meeting permanent obstructions to trenches, such as drains, water pipes or cables. The thickness of cover and of walls of ammunition stores should be included.

iii. Details of accommodation and water supply.

iv. A description of the defence electric lights which are in or near the work and which bear on water covered by the fire of the work, stating briefly how the lights are emplaced, the position of the engine room and directing station and details of cable sizes and routes.

v. Any orders affecting the control of lights and a description of the scheme for allocating the lights to co-operate with the guns.

vi. A plan of the electric light lay-out showing the arcs.

vii. A plan showing the telephonic and other communications, the position of telephone rooms and speaking tubes, the route taken by the wires, the nature of the wires (whether air line or cable) and the position of wireless receiving and transmitting stations.

viii. Engineer preparations for defence, comprising a summary of all defence works that have to be carried out in the precautionary and war periods against the possibility of a surprise attack, including all trenches, machine-gun posts, fences, wire entanglements, etc., for the protection of the battery and its command posts, electric light emplacements, etc.

ix. Statements of the tools and materials which will be available for the works above referred to and of the transport and labour which is required and obtainable.

4. *Additional engineer works.*—In addition to the above details for the fort record books of each battery and fire

command, it is also necessary to include in the general scheme of the defence full details of all engineer works required that are not directly connected with the fixed artillery defences. The principal item will be the works required on the land fronts, for which a full description, with plans, tables of tools, materials, labour and transport, should be prepared in advance. There may also be works in connection with anti-aircraft defence and the various administrative services of the fortress, *e.g.* the provision of accommodation, water supply and washing and sanitary facilities for the war garrison, all of which should be specified in the engineer defence scheme.

122. Duties of Royal Engineers in a coast fortress

1. Engineer garrisons at defended ports comprise personnel for :—

- i. Engineer headquarters attached to fortress headquarters.
- ii. Works services.
- iii. Defence electric lights.
- iv. Battery engine rooms.
- v. Defence works.
- vi. Anti-aircraft searchlights.
- vii. Mobile units for beach lighting and other duties.

2. The personnel falls under the following categories :—

- i. Regular R.E. organized as fortress companies.
- ii. Territorial Army R.E. organized in companies.
- iii. Local force engineers, usually organized in companies.

3. *Engineer headquarters, officers and other ranks* :—

Engineer headquarters consists of the C.E., or C.R.E., with his staff. The C.E., or C.R.E., is the adviser to the fortress commander on all engineering matters.

The duties of engineer headquarters in peace are the control and administration of works services, administration and training of all engineer units in the garrison, and the responsibility for the efficient maintenance of all defence plant and stores.

In war the duties include the above and in addition the organization of new defence works, beach defences, protection of vulnerable points, war hutting and all additional engineer requirements in accordance with the demands of the local defence scheme. Officers may also have to be found for special appointments such as sector commander, fortress staff officer, etc.

4. *Works services*.—Officers for works services and a detachment of staff for engineer services, including mechanists for electrical and mechanical duties, are posted to each fortress. Their peace duties will be as laid down in Regulations for

Engineer Services. These may include the operation of power stations for supply of barrack electric light and of pumping stations for water supply, to supplement or in the absence of local municipal undertakings. In war the peace duties outlined above will be continued, except that barrack maintenance will be reduced to a minimum and certain items of new construction postponed. Additional supervising staff and labour will be required to carry out the items of defence works, hutting, etc., referred to in para. 3, above. The numbers required and source of supply should be noted in the local defence scheme.

5. *Defence electric lights.*—Manning personnel of officers and other ranks are borne on the establishment of the fortress company, R.E., or Territorial Army, R.E. Peace-time duties are the maintenance of the defence electric lights plant in a state of efficiency and the carrying out of the special training laid down. The latter will include periodical defence practices in co-operation with the artillery and, when possible, in conjunction with the Navy and Air Force. War duty comprises the continuous night manning of the defence electric light defences. For details, *see* Sec. **111**.

6. *Battery engine rooms.*—Officers and other ranks are on the establishment of the fortress company, R.E. Peace-time duties are the care and operation of plant (both in the battery engine room and at the gun positions) for the use of the artillery during gun practice. In war a full-time manning personnel is required.

7. *Defence works.*—For the construction and maintenance of defensive field works, and for minor repairs to fixed defences, a section of the fortress company, R.E., may be specially allotted for this duty in peace. In war they will be told off to special items of new construction included in the defence scheme.

8. *Anti-aircraft searchlights.*—Companies for anti-aircraft searchlight duties will be allotted to a fortress according to requirements, in accordance with the authorized establishments. Personnel for plotting rooms, etc., will be provided in addition to meet local needs. Peace-time duties will include the special training laid down and periodical practices with aircraft and the other arms. Provision must be made in war for the continuous manning of the plotting rooms by day and night, and of the searchlights during the hours of darkness.

9. *Mobile units.*—In certain stations the fortress company includes a mobile section for duty in connection with beach defence or on the land front, while at others the local defence force may include one or more field companies for general duties and for mobile warfare.

APPENDIX

GENERAL INSTRUCTIONS FOR THE CONSTRUCTION OF A REAR DEFENSIVE POSITION

The rear zone defences will be constructed on the following general principles :—

They will, as a rule, consist of :—

(*a*) Front or observation line, mainly sited on a forward slope in order to retain observation over the immediate foreground.

(*b*) Support line, or line of resistance, sited as far as possible on a reverse slope, at an average distance of 200 yards in rear of the front line.

(*c*) Reserve line, sited as far as possible on a reverse slope, or at all events on a forward slope screened from the enemy's view. The distance in rear of the support line should be between the limits of 500 and 600 yards.

(*d*) Defended localities in or close behind the line.

In no case should the general line of a trench be straight ; it must be waved.

Trenches should bend backwards where they cross valleys so as to form a "pocket," which must be well wired. The amount of trenchwork in the bottom of a valley should be reduced to a minimum, in view of the probability of the enemy gassing the valley. Communication trenches should be kept well up the slopes and may often serve as fire trenches to bring cross fire over the valley.

On account of gas, trenches should not be sited in woods or copses unless this is unavoidable. In such cases the vicinity must be cleared of undergrowth.

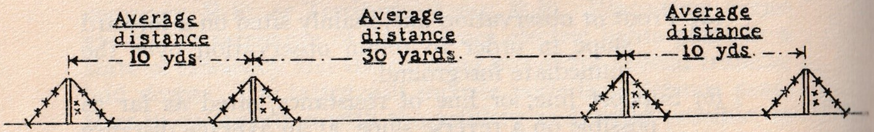
Communication trenches between front and support lines should be at average intervals of 250 to 300 yards and between support and reserve lines at average intervals of 500 to 700 yards. Communication trenches should run in a direction inclined to that of the fire trenches and should be provided with fire stops at intervals to bring a cross fire in case of penetration. They should be wired on the side of the enemy.

The trace and section of fire and communication trenches will generally be in accordance with Plate **31**. Where it is necessary to protect all parts of a trench from being enfiladed from some commanding point, it may be necessary

to employ a simple zigzag trace. Templates must always be used to ensure trenches being made to correct section.

In all trenches ample drainage *must* be made *at the same time* as the construction of the trench and for the *final* depth of the trench. Sump pits should only be used on flat sites; drains should be usually brought out to ground level. Drains through the front parapet should be aligned so that the enemy cannot see into the trench. The sides of drains should be at slopes of 1/1.

Wiring.—The standard type of wire entanglement for fire trenches to be aimed at is as follows :—



Pickets to project about 4 feet to 4 feet 6 inches and to be about 7 feet apart. Short anchoring pickets to be in echelon with the large ones. Seven or eight horizontal wires to be used. The stay wires and top wire should be of plain wire. If material is available loose wire should be added between the belts.

In plan each belt of wire should undulate, but the undulations should all be independent of each other and of the trench. The distance of the inner belt from the trench must not be less than 50 yards.

One belt of wire will suffice for communication trenches.

In beginning wiring, priority should be given :—

i. In the case of trenches on forward slopes much exposed to fire, *to the support trenches* on reverse slopes which form the main line of resistance.

ii. In the case of trenches on forward slopes at some distance from hostile positions, and not exposed to close observation or where the front trench is on the reverse slope, *to the front trenches.*

Gaps of five yards' width should be left every 100 yards in the front and reserve wire and every 50 yards in the support wire. Tactical gaps will be made as directed. Gaps of about 30 yards' width must be left on both sides of main roads to allow for "overland" tracks and smaller ones at all used tracks.

Where road gaps do not exist, gaps in wire and crossings over trenches for artillery must be left about every 800 yards.

All gaps to be marked by notice boards GAP fixed to posts placed facing along the wire, alternate boards facing

differently. Artillery crossings to be marked by a bundle of straw attached to a post. Gaps through the different belts of wire to be staggered.

Knife rests or other material must be prepared and stacked on the site ready to close all gaps.

Machine gun positions will be selected by a machine gun officer. If time permits, the emplacements will be of the deep dug-out, champagne type (as shown in Plate **32**). If time does not permit of this type being made, the emplacements will consist of open pits with a firing table of earth, connected by a winding trench, according to the type furnished by the machine gun officers. The excavated earth will all be removed from the site.

Machine gun emplacements will all be made under camouflage, and great care must be taken to instruct the working parties to avoid doing things which would allow aerial observers to detect what work is going on. Tracks beaten on the ground from the emplacements to a spoil heap or any one spot must not be allowed. Dummy trenches may often be usefully employed running from some road or trench suitable for concealing tracks to another road, etc. This dummy trench would pass close to the emplacements and the excavated earth would be deposited along it.

Where there are patches of ploughed land, the emplacements should, if possible, be in a patch of plough, or it may be convenient to plough the site before beginning to work.

All machine gun emplacements must be marked on the ground by notice boards.

In working out schemes for defended localities in this area, the following points should be borne in mind in the case of villages :—

The villages are usually surrounded by a network of gardens with thick hedges and many trees, while as a rule the roads are winding. This makes it practically impossible to obtain any extended field of fire in the village itself, and at the same time the free use of gas shell would render occupation impossible without special precautions which are possible only to a very limited extent.

Therefore the soundest course would appear to be the establishment, at tactical points *immediately outside* the village, and its dense enclosures, of strong wired-in posts (keeps), with dug-outs for garrison, screened from view as far as possible. These posts (which would be usually well inside the circuit of trenches surrounding the village as a whole) should afford mutual support and command approaches to and exits from the village. Good communications from these posts to the rear should be provided. The garrison of the posts should

be mainly light machine gun personnel, so as to reduce personnel and sheltered accommodation to a minimum.

Under certain favourable conditions it may be advisable to establish within the inhabited area light machine gun positions in specially protected houses or cellars, whence exceptional enfilade fire can be obtained. In this connection the use of any caves in a village should be considered. In the event of such positions being adopted, special precautions must be taken against gas.

REINFORCED CONCRETE COMPANY HEADQUARTERS.

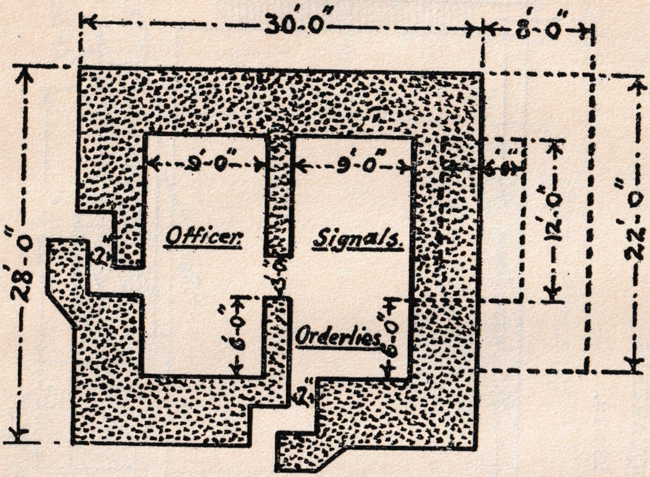


FIG. 1.

DEEP DUG-OUT.

(FOR COMPANY OR BATTERY HEADQUARTERS.)

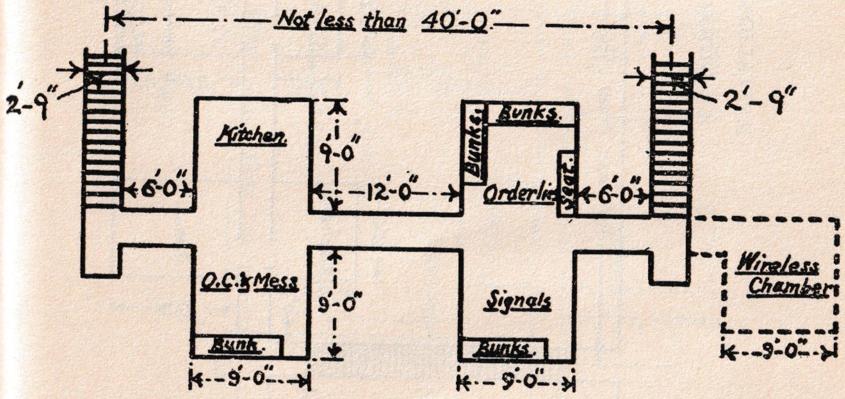
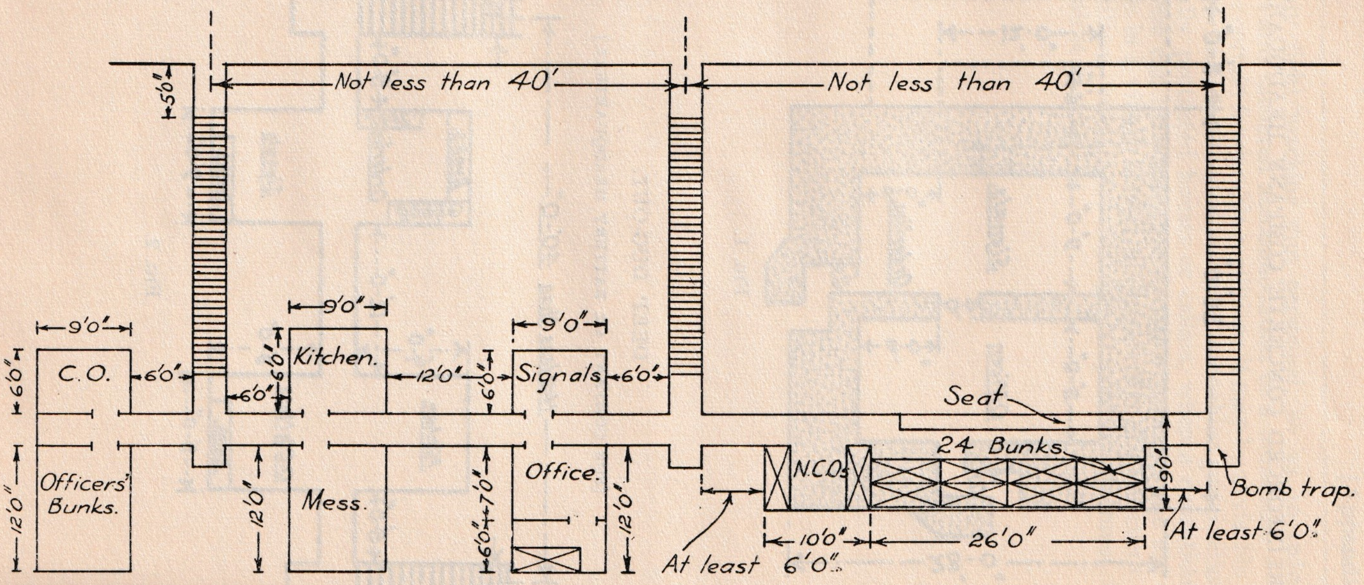


FIG. 2.

BATTALION BATTLE HEADQUARTERS.

WITH ACCOMMODATION FOR 28 MEN.



BRIGADE HEADQUARTERS.

WITH ACCOMMODATION FOR PERSONNEL.

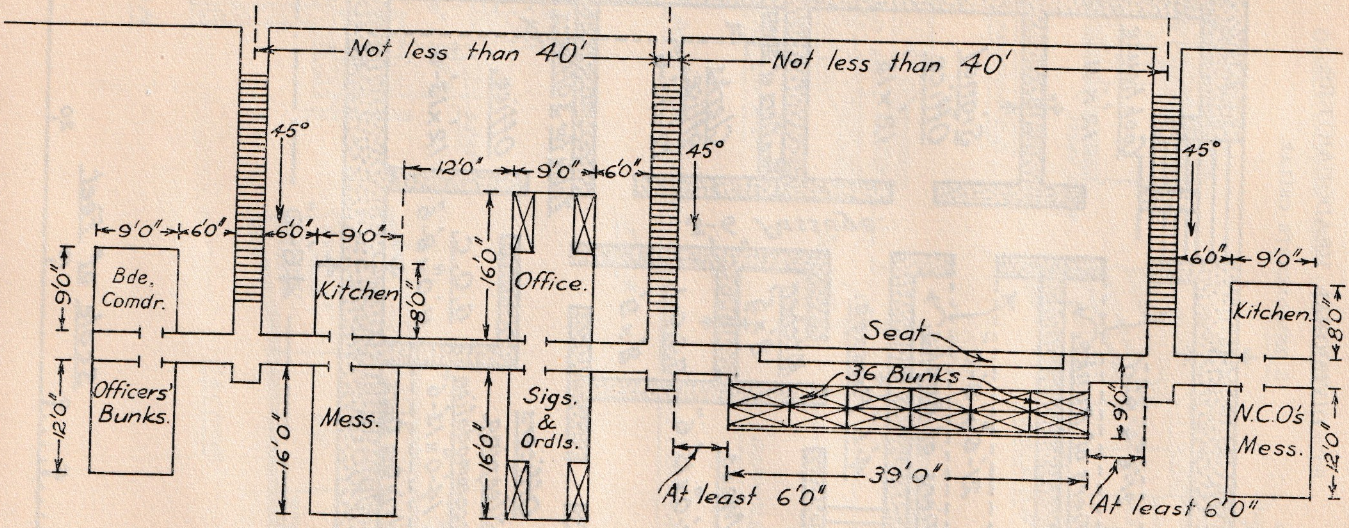
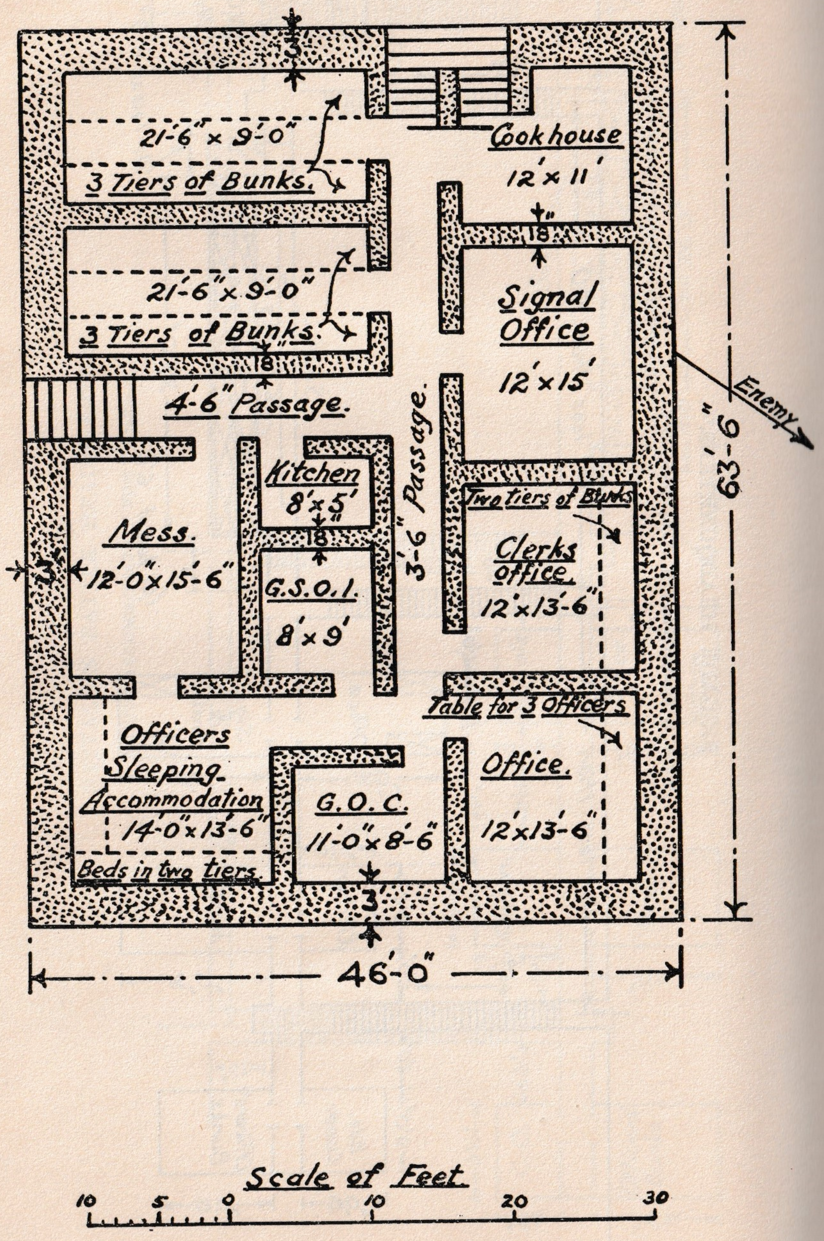


Plate 3

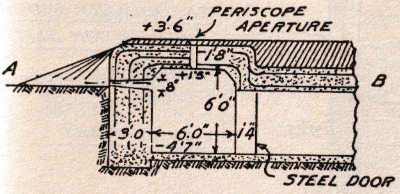
DIVISIONAL HEADQUARTERS.

IN CONCRETE CELLAR.



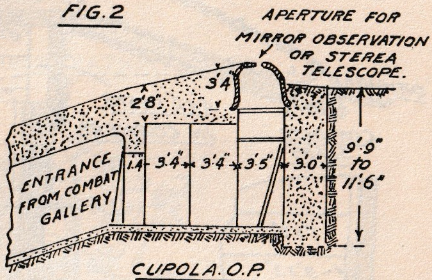
OBSERVATION AND COMMAND POSTS.

FIG. 1



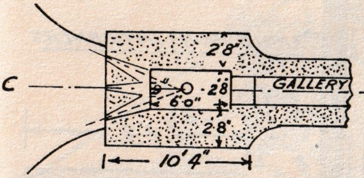
CONCRETE. O.P.
SECTION. C.D.

FIG. 2

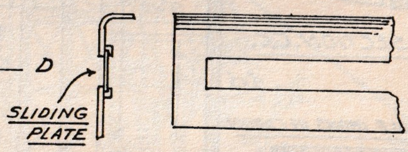


CUPOLA. O.P.

FIG. 3



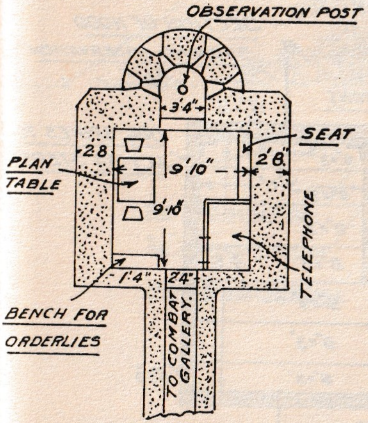
PLAN ON A.B.



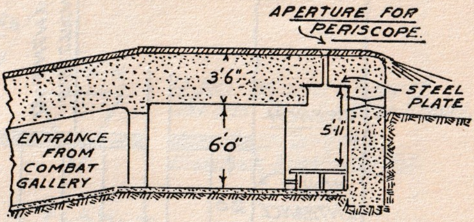
LOOPHOLE PLATE.

COMMAND POST FOR BATTALION OR BRIGADE COMMANDER.

FIG. 4.



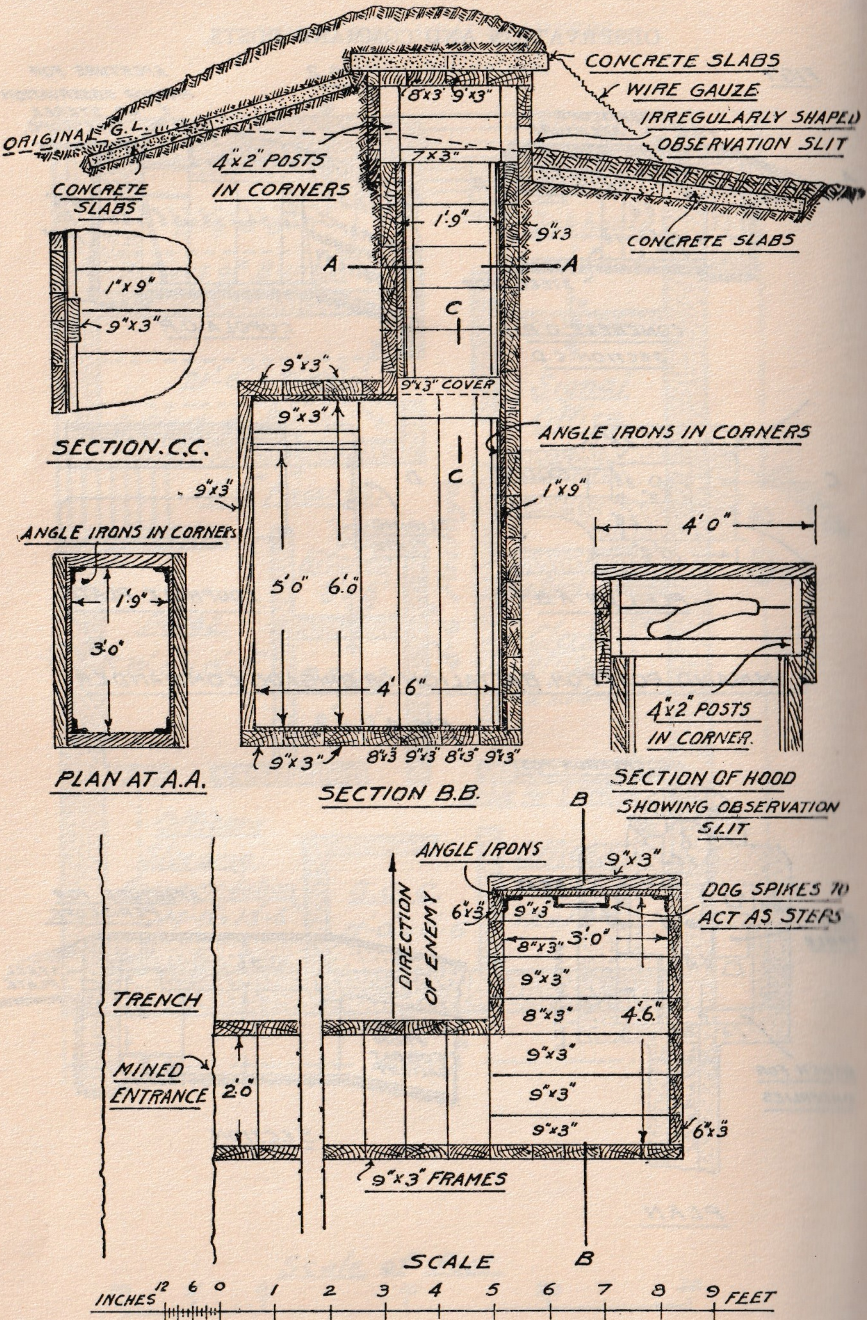
PLAN



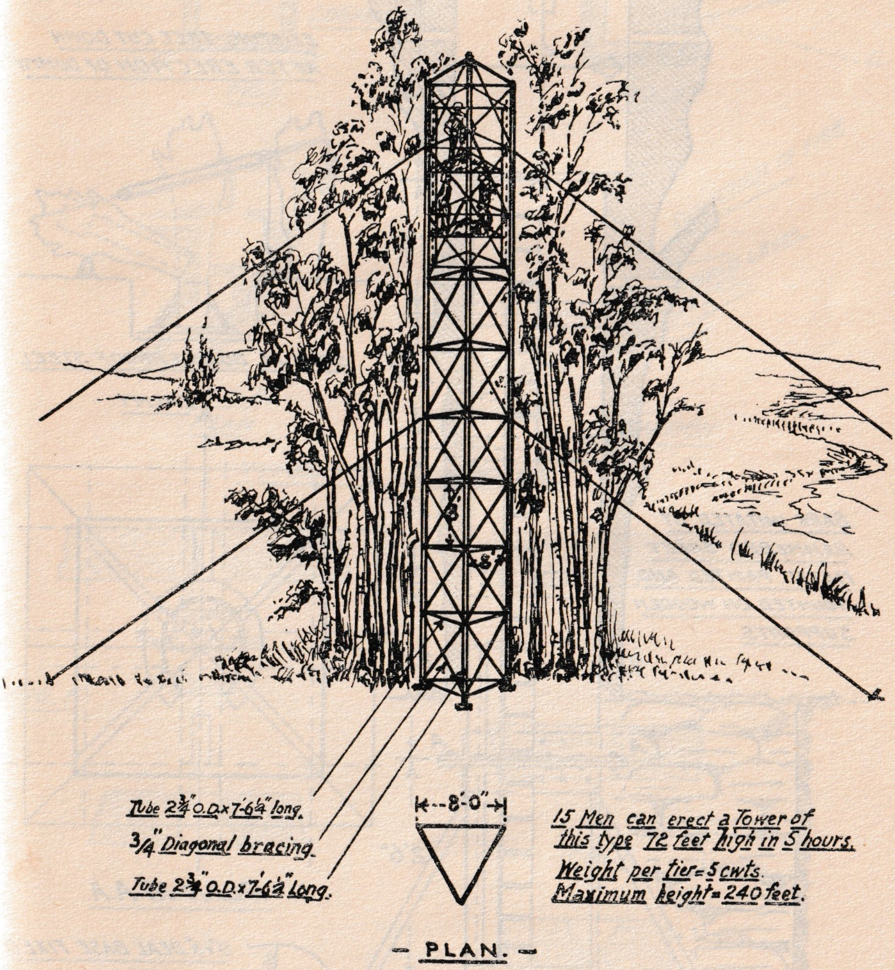
SECTION.

Plate 6.

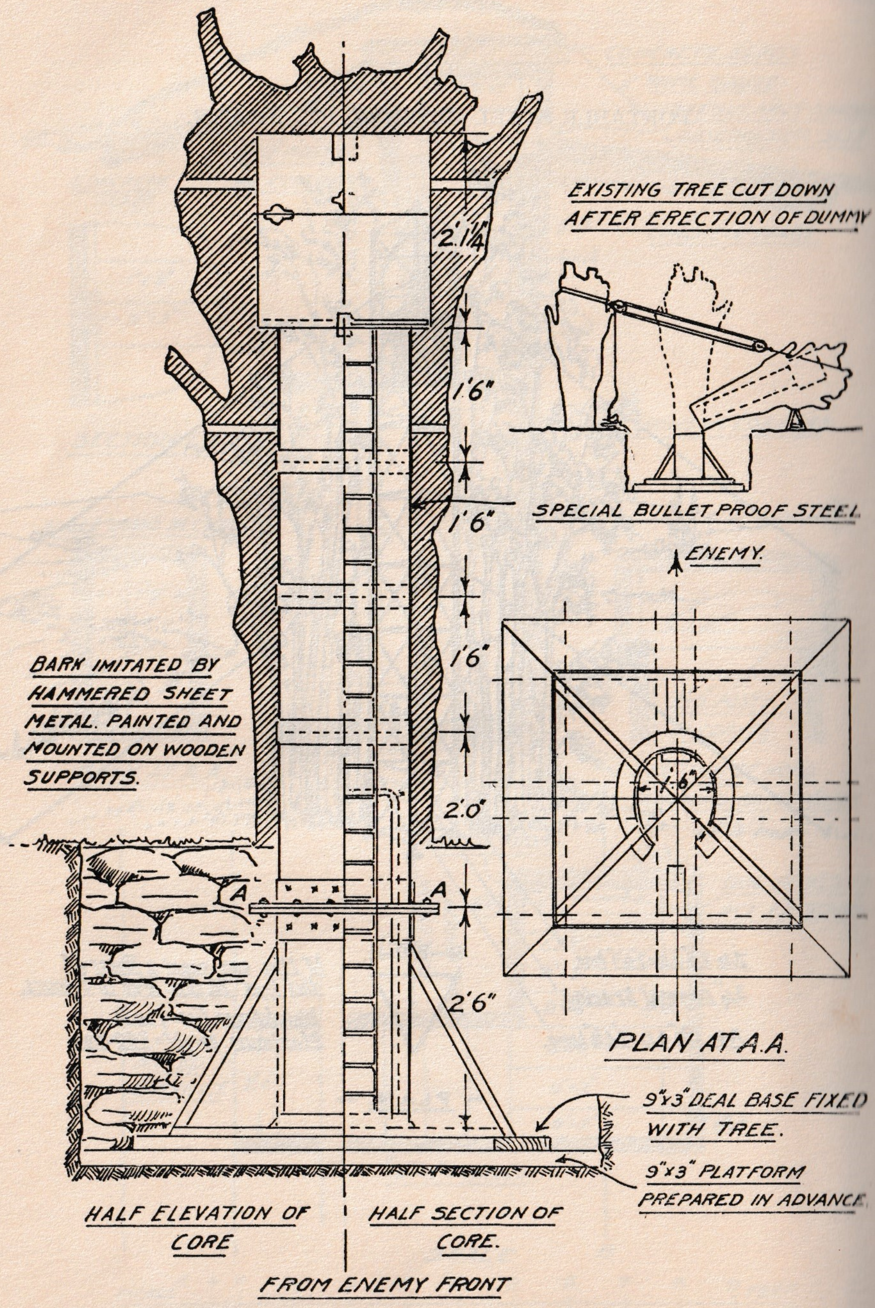
SPLINTER-PROOF OBSERVATION POST.



PORTABLE STEEL OBSERVATION TOWER.



OBSERVATION TREE.



CONCRETE CASEMATES.

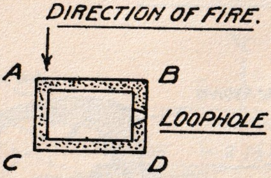


FIG.1.

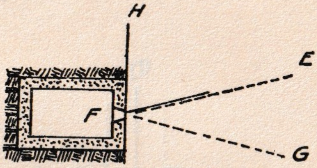


FIG.2.

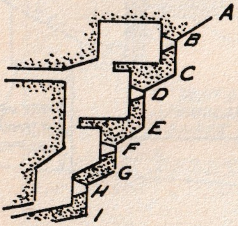


FIG.3.
PLAN

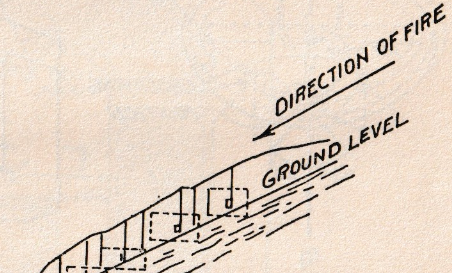
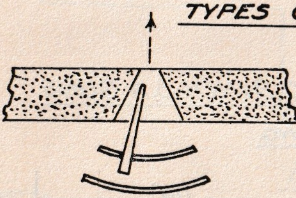


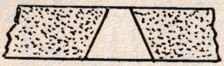
FIG.4.
ELEVATION

TYPES OF LOOPHOLES.



PLAN

FIG. 5.



SECTION

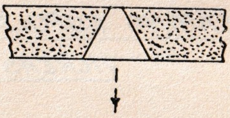


FIG.6.

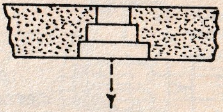


FIG.7.

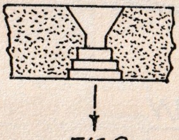
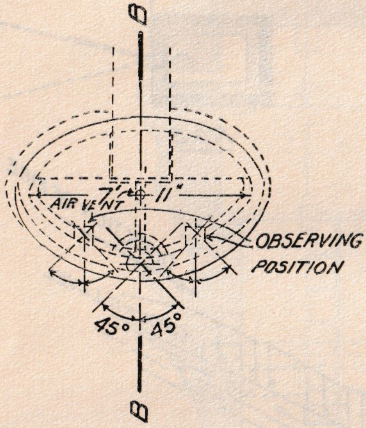


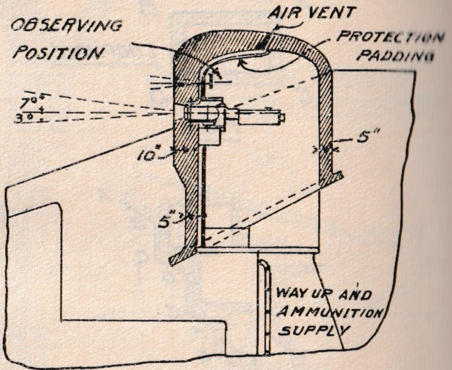
FIG.8.

MACHINE GUN CUPOLA.

VICKERS ARMSTRONG.



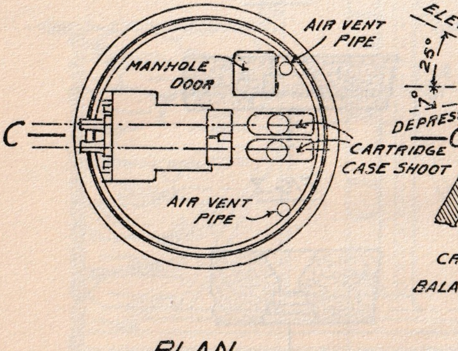
PLAN



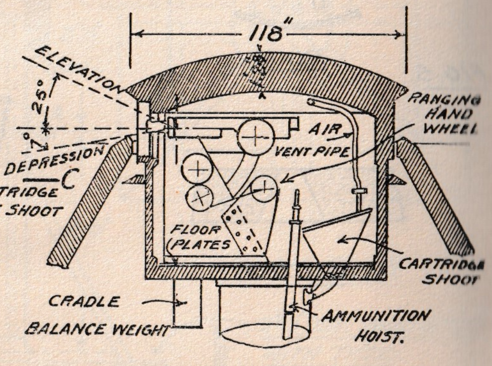
SECTION B.B.

DISAPPEARING CUPOLA FOR TWO 3 INCH. S.A. GUNS.

VICKERS ARMSTRONG.

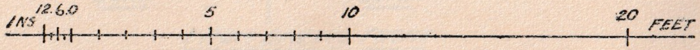


PLAN



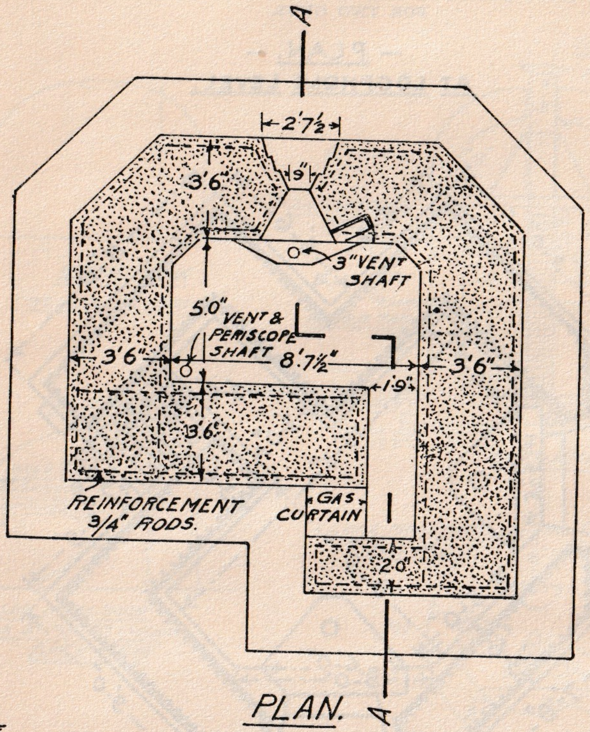
SECTION C.C.

SCALE OF FEET

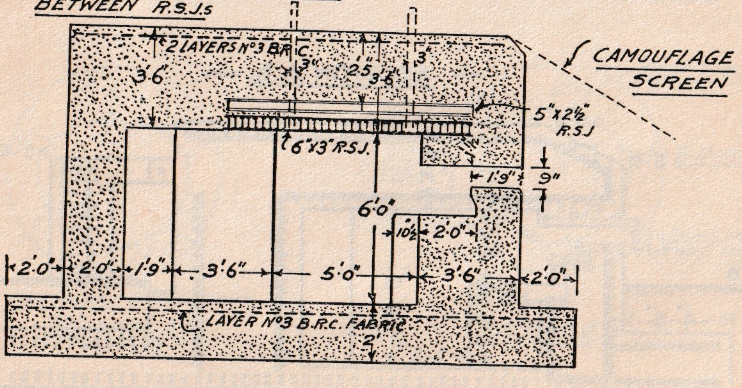


REINFORCED CONCRETE MACHINE GUN EMPLACEMENT.

FOR ONE GUN.



PLAN.



SECTION. A.A.

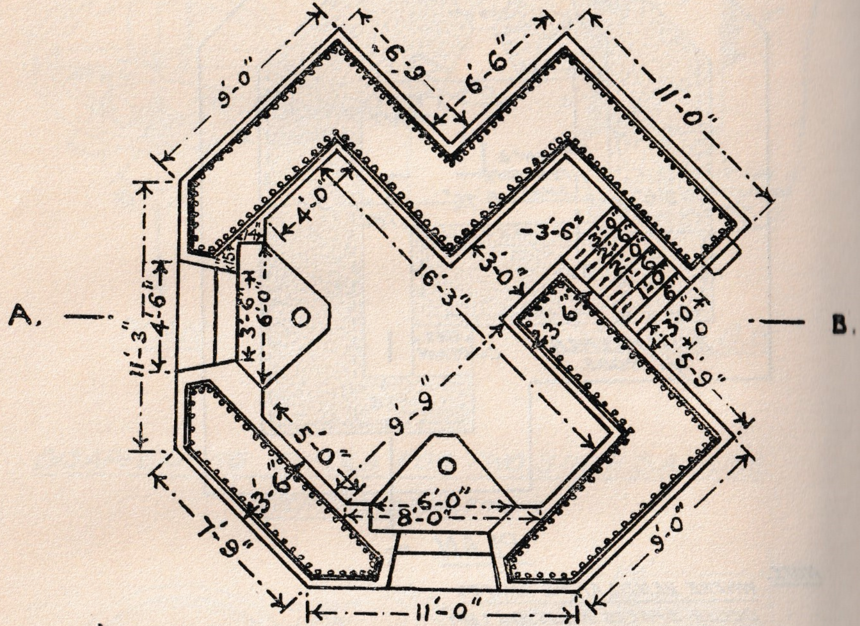
Plate 12.

REINFORCED CONCRETE MACHINE GUN EMPLACEMENT.

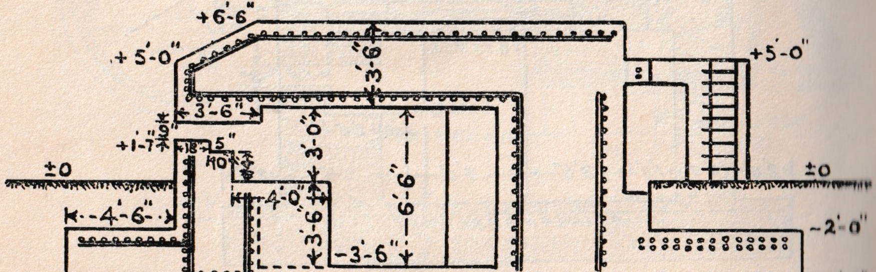
FOR TWO GUNS.

— PLAN. —

AT LOOPHOLE LEVEL.

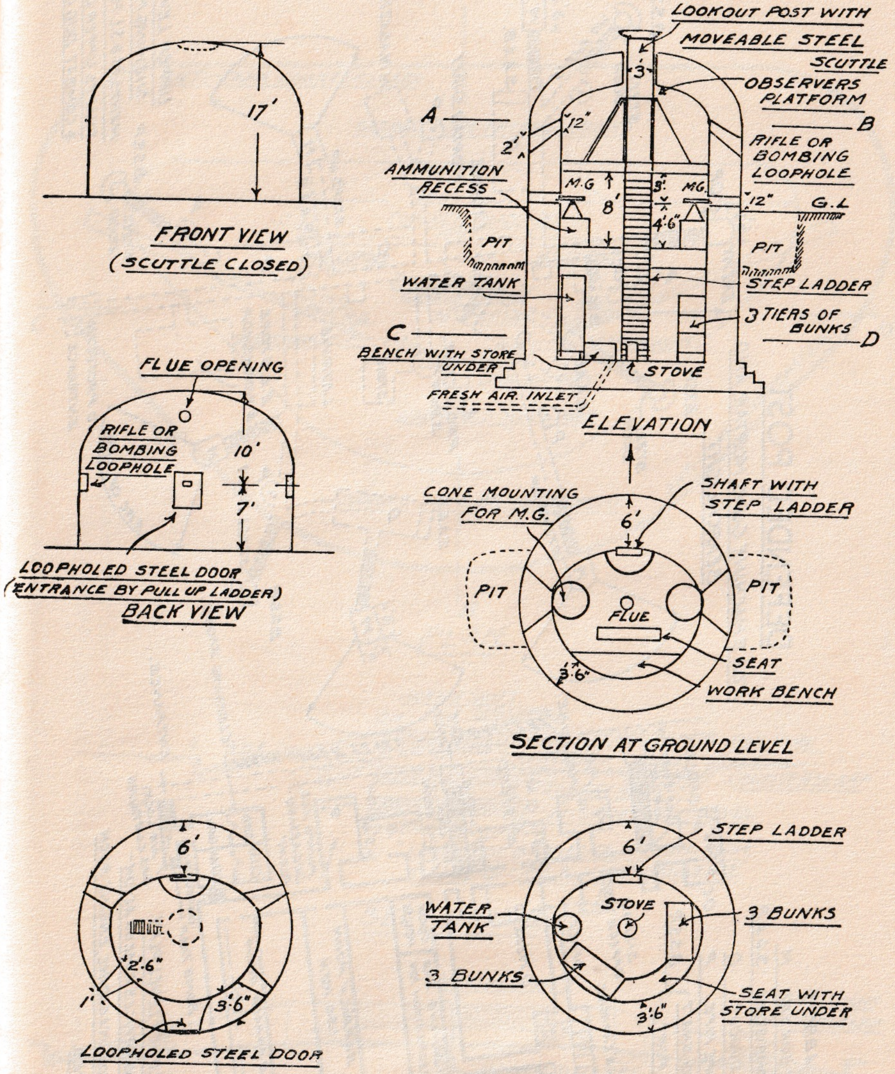


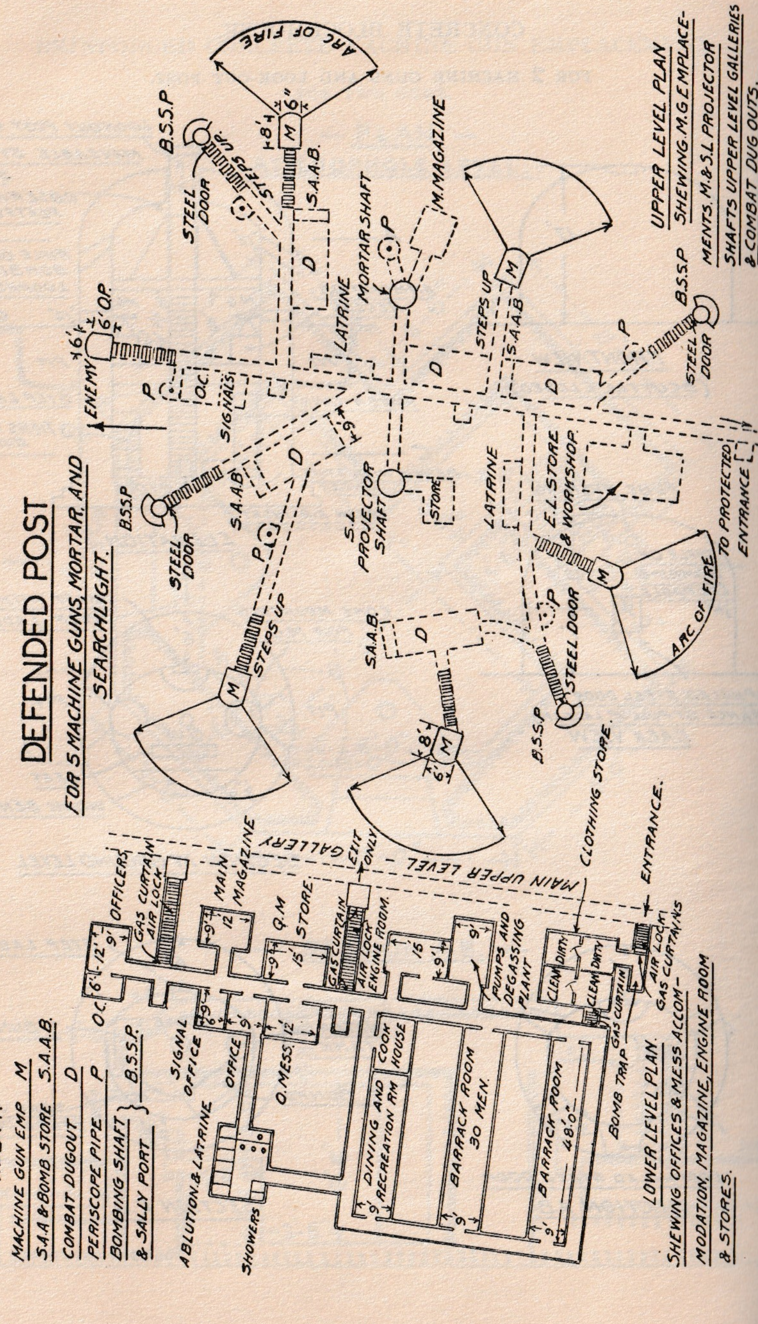
— SECTION A.B. —



CONCRETE BLOCKHOUSE.

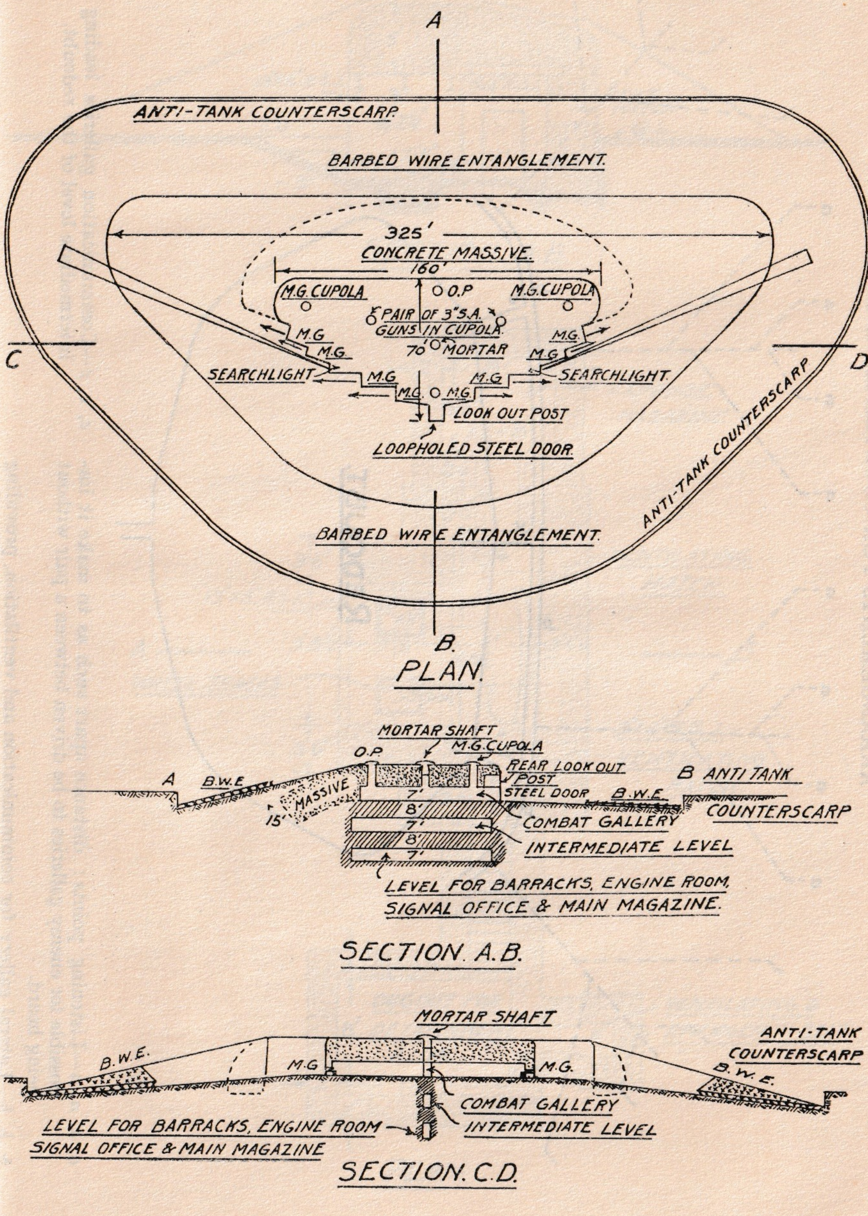
FOR 2 MACHINE GUNS AND LOOK-OUT POST.



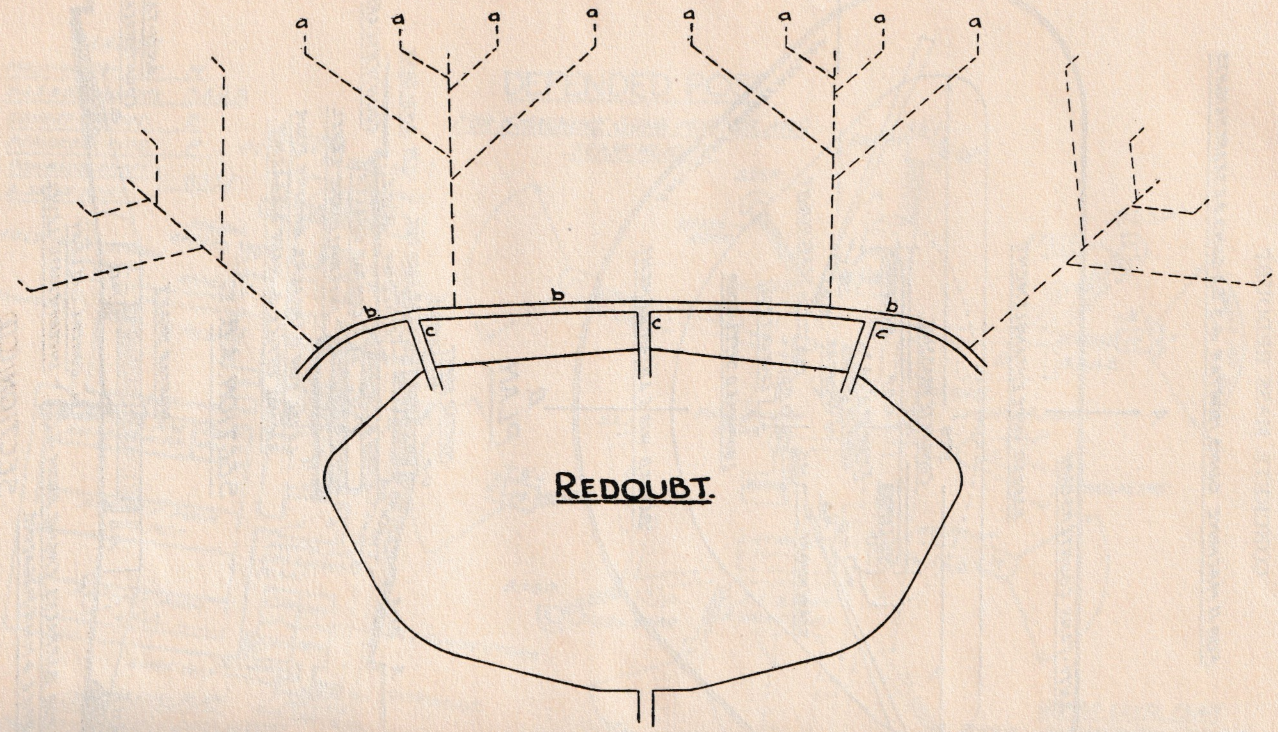

DEFENDED POST
FOR 5 MACHINE GUNS, MORTAR, AND SEARCHLIGHT.
ABBRNS.
MACHINE GUN EMP M
S.A.A & BOMB STORE S.A.A.B.
COMBAT DUGOUT D
PERISCOPE PIPE P
BOMBING SHAFT & SALLY PORT B.S.S.P.
UPPER LEVEL PLAN
SHEWING M.G. EMPLACEMENTS, M. & S.L PROJECTOR SHAFTS UPPER LEVEL GALLERIES & COMBAT DUG OUTS.
LOWER LEVEL PLAN.
SHEWING OFFICES & MESS ACCOMMODATION, MAGAZINE, ENGINE ROOM & STORES.
ENEMY
6' O.P.
ARC OF FIRE
STEPS UP
STEEL DOOR
B.S.S.P
S.A.A.B.
LATRINE
MORTAR SHAFT
M. MAGAZINE
O.C.
SIGNALS
S.L PROJECTOR SHAFT
STORE
E.L. STORE & WORKSHOP
TO PROTECTED ENTRANCE
MAIN UPPER LEVEL GALLERY
EXIT ONLY
OFFICERS
GAS CURTAIN AIR LOCK
MAIN MAGAZINE
Q.M STORE
GAS CURTAIN AIR LOCK ENGINE ROOM.
PUMPS AND DEGASSING PLANT
CLOTHING STORE.
ENTRANCE.
AIR LOCK GAS CURTAINS
CLEAN
DIRTY
GAS CURTAIN
BOMB TRAP
SIGNAL OFFICE
OFFICE
O. MESS
COOK HOUSE
DINING AND RECREATION RM
BARRACK ROOM 30 MEN.
BARRACK ROOM 48'0"
ABLUTION & LATRINE
SHOWERS

CONCRETE MASS REDOUBT

FOR 11 MACHINE GUNS, MORTAR, 4-3" S.A GUNS & 2 SEARCHLIGHTS.



ARRANGEMENTS FOR COUNTER-MINING

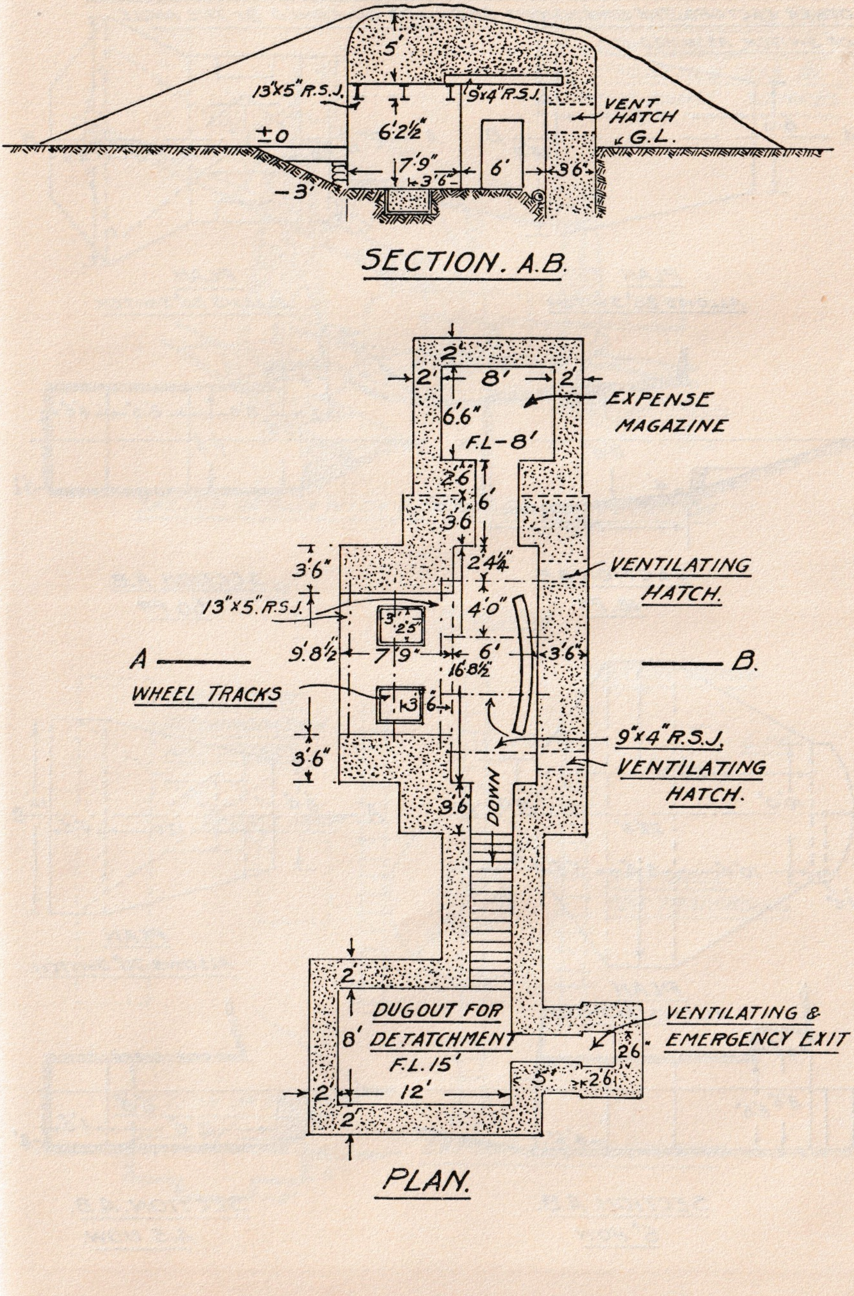


a, a, a, a—Listening points; distance apart such as to make it impossible for enemy galleries to be driven between a pair without being heard.

b, b, b—Lateral gallery for communication and ventilation, providing starting points for the forward galleries.

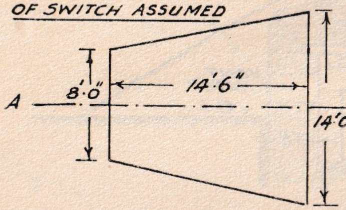
c, c, c—Communication galleries leading from the intermediate level of the redoubt.

SHELL-PROOF EMPLACEMENT FOR 18-POUNDER.

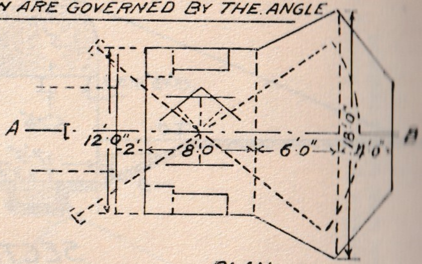


DIMENSIONS OF GUN EMPLACEMENTS.

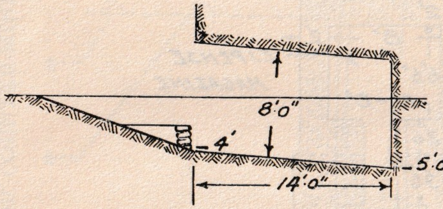
THE DETAILS IN ANY PARTICULAR CASE WILL VARY WITH THE GROUND AND OTHER FACTORS. THE DIMENSIONS GIVEN ARE GOVERNED BY THE ANGLE OF SWITCH ASSUMED



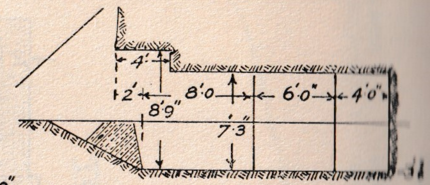
PLAN
ALLOWS 80° SWITCH



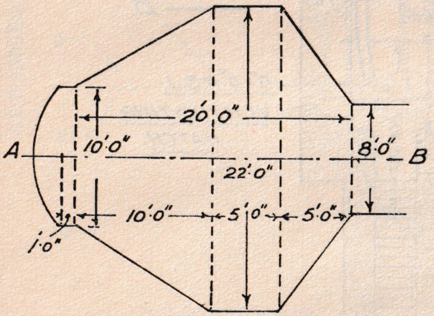
PLAN.
ALLOWS 80° SWITCH.



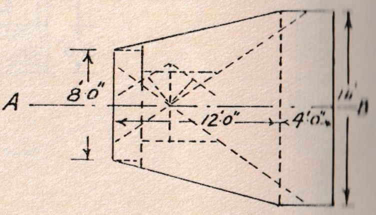
SECTION. A.B.
18. PR



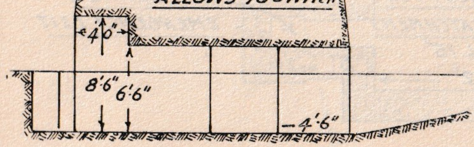
SECTION A.B.
60 PR



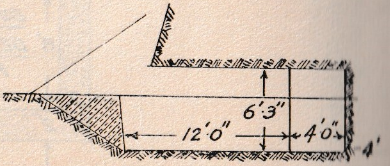
PLAN
ALLOWS 70° SWITCH



PLAN
ALLOWS 70° SWITCH



SECTION. A.B.
6" HOW

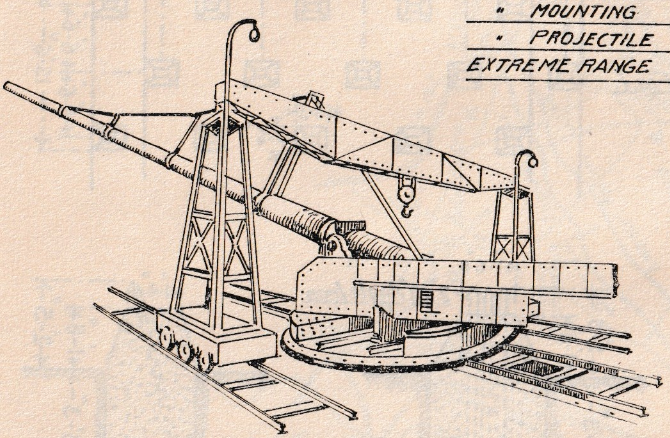


SECTION. A.B.
4·5. HOW.

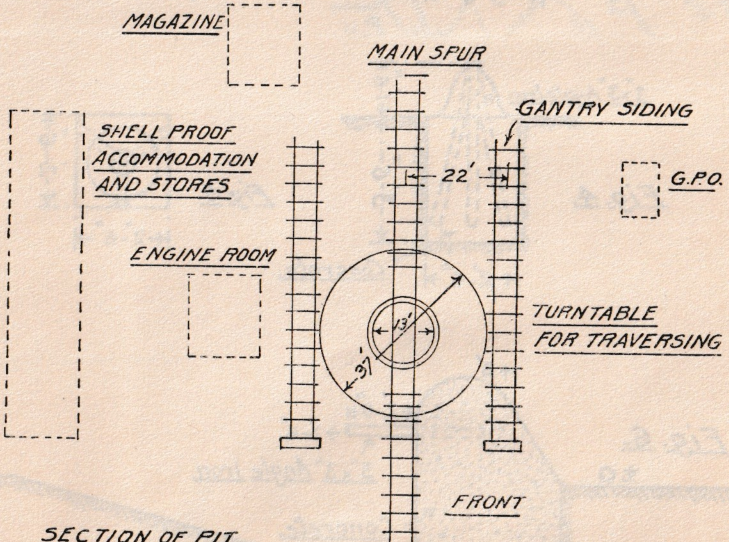
EMPLACEMENT FOR 9·13-INCH GUN.

USED FOR THE BOMBARDMENT OF PARIS. APRIL 1918.

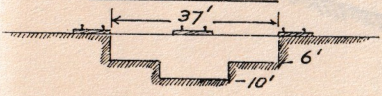
WEIGHT OF GUN	154 TONS
" MOUNTING	236 "
" PROJECTILE	273 lb.
EXTREME RANGE	90 MILES.



SKETCH OF GUN WITH GANTRY CRANE IN POSITION.



SECTION OF PIT



LAY-OUT AT GUN POSITION

TANK OBSTACLES.

Fig. 1.

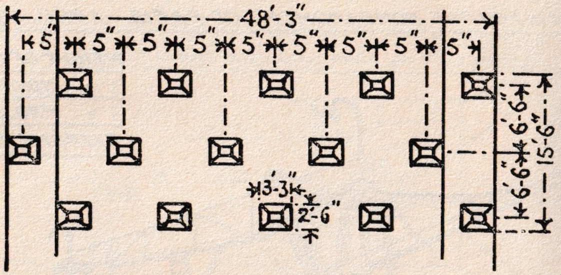


Fig. 2.

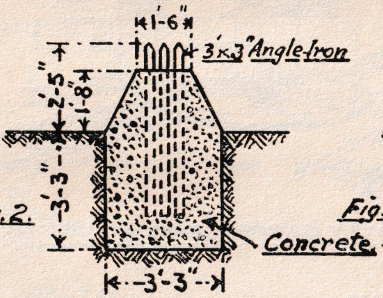


Fig. 3.

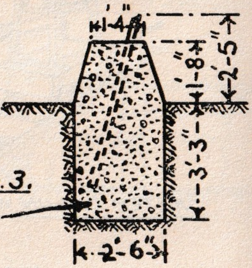


Fig. 4.

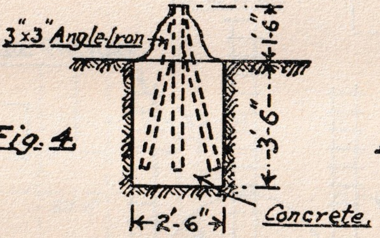


Fig. 5.

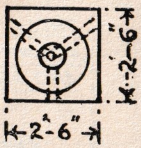
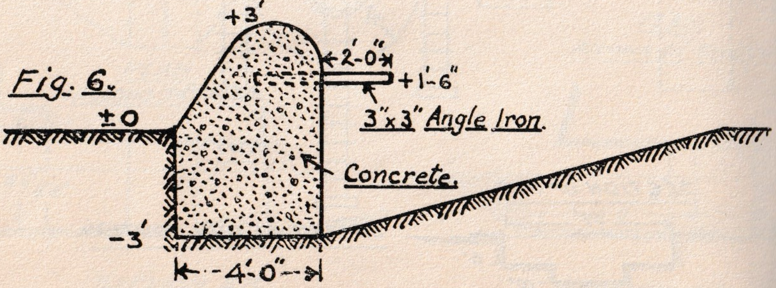


Fig. 6.



TYPICAL EXAMPLE OF FORWARD ROAD SYSTEM.

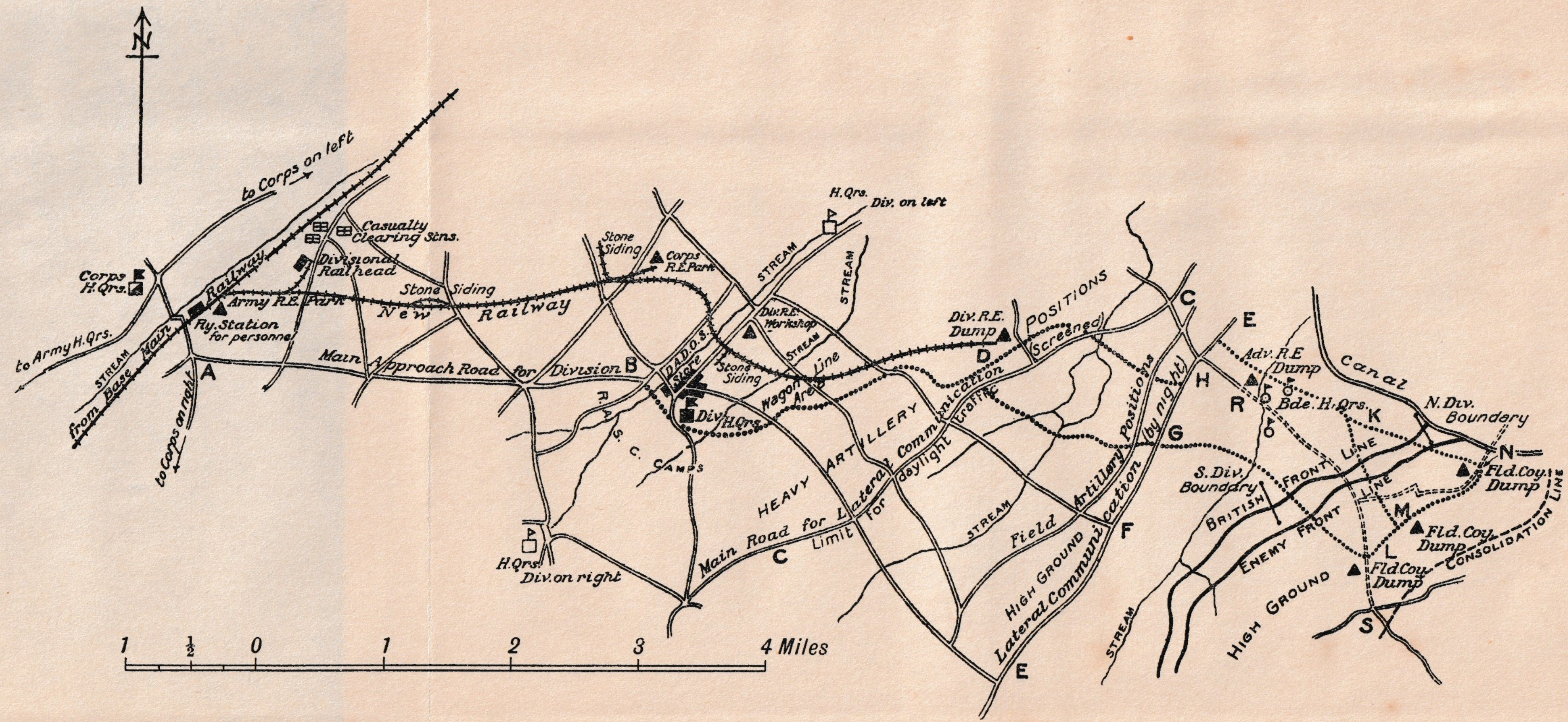
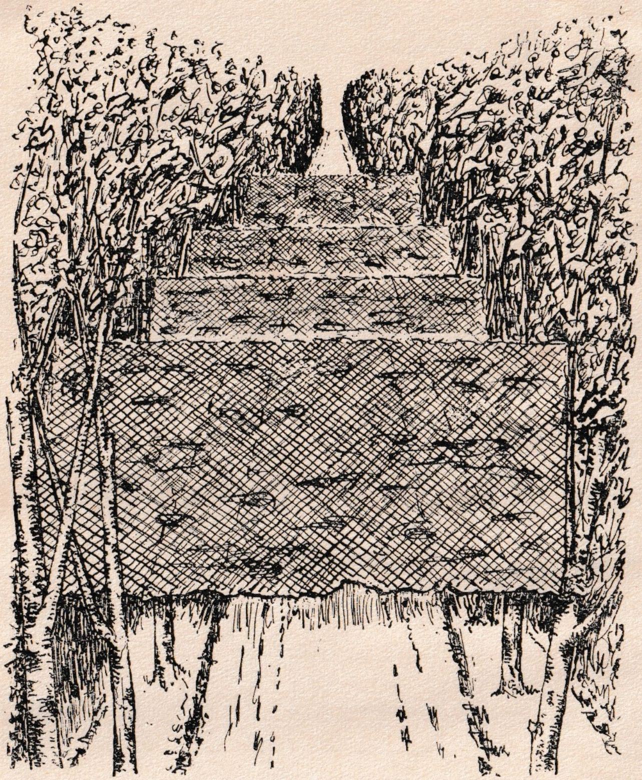


Plate 21.

Plate 22.

SCREENING FROM ENFILADE VIEW.

TRAFFIC TO PASS UNDER SCREENS.

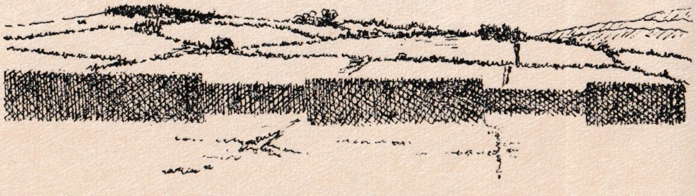


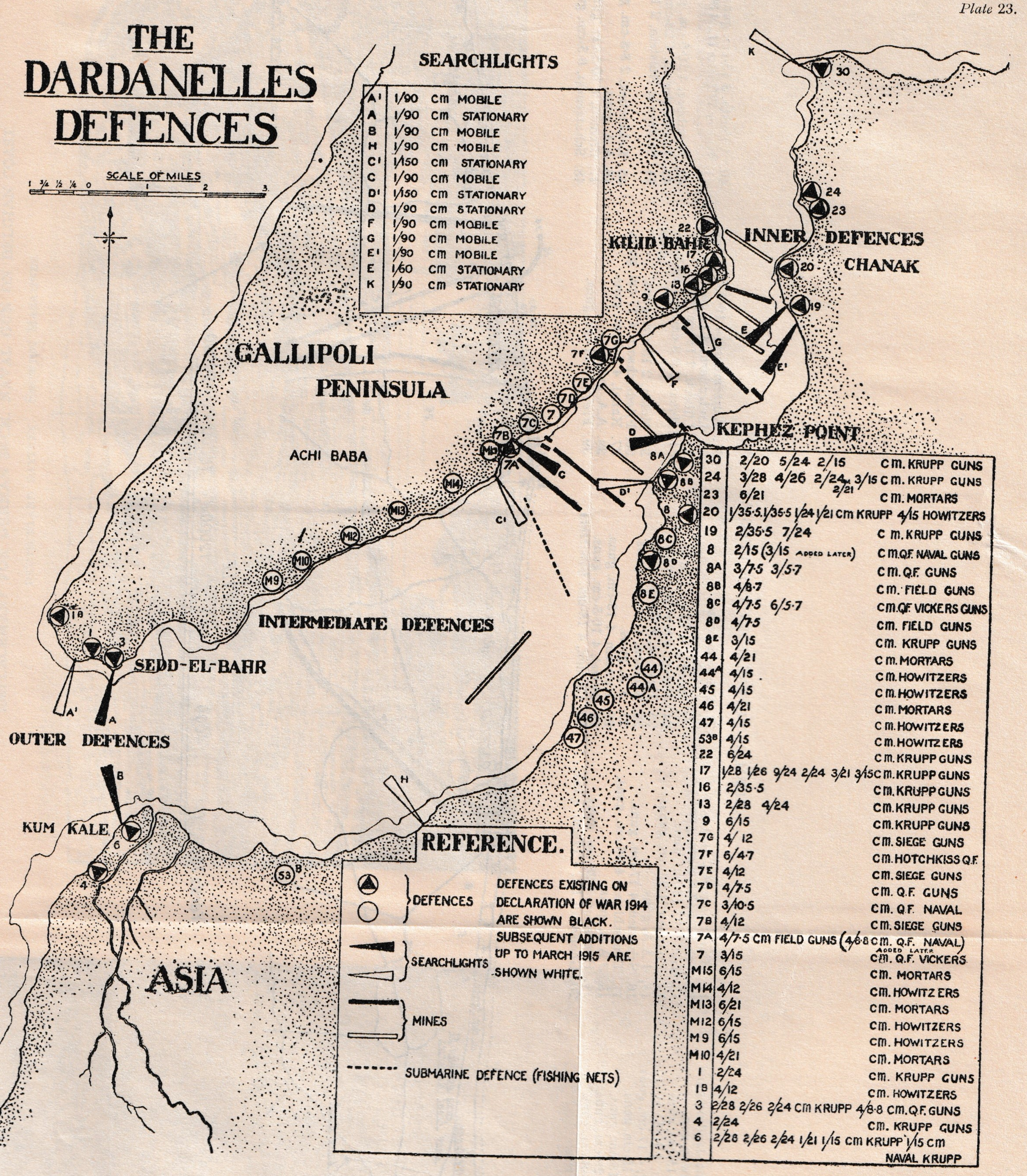
SCREENS IN ECHELON.

FOR ROAD PARALLEL TO FRONT LINE.

Enemy view of road unscreened.

After screening.





SEARCHLIGHTS

A'	1/90 cm MOBILE
A	1/90 cm STATIONARY
B	1/90 cm MOBILE
H	1/90 cm MOBILE
C'	1/150 cm STATIONARY
C	1/90 cm MOBILE
D'	1/150 cm STATIONARY
D	1/90 cm STATIONARY
F	1/90 cm MOBILE
G	1/90 cm MOBILE
E'	1/90 cm MOBILE
E	1/60 cm STATIONARY
K	1/90 cm STATIONARY

30	2/20 5/24 2/15	CM. KRUPP GUNS
24	3/28 4/26 2/24 2/21 3/15	CM. KRUPP GUNS
23	6/21	CM. MORTARS
20	1/35·5 1/35·5 1/24 1/21 CM KRUPP 4/15 HOWITZERS	
19	2/35·5 7/24	CM. KRUPP GUNS
8	2/15 (3/15 ADDED LATER)	CM. Q.F. NAVAL GUNS
8A	3/7·5 3/5·7	CM. Q.F. GUNS
8B	4/8·7	CM. FIELD GUNS
8C	4/7·5 6/5·7	CM. Q.F. VICKERS GUNS
8D	4/7·5	CM. FIELD GUNS
8E	3/15	CM. KRUPP GUNS
44	4/21	CM. MORTARS
44A	4/15	CM. HOWITZERS
45	4/15	CM. HOWITZERS
46	4/21	CM. MORTARS
47	4/15	CM. HOWITZERS
53B	4/15	CM. HOWITZERS
22	6/24	CM. KRUPP GUNS
17	1/28 1/26 9/24 2/24 3/21 3/15	CM. KRUPP GUNS
16	2/35·5	CM. KRUPP GUNS
13	2/28 4/24	CM. KRUPP GUNS
9	6/15	CM. KRUPP GUNS
7G	4/12	CM. SIEGE GUNS
7F	6/4·7	CM. HOTCHKISS Q.F.
7E	4/12	CM. SIEGE GUNS
7D	4/7·5	CM. Q.F. GUNS
7C	3/10·5	CM. Q.F. NAVAL
7B	4/12	CM. SIEGE GUNS
7A	4/7·5 CM FIELD GUNS (4/8·8 CM. Q.F. NAVAL) ADDED LATER	
7	3/15	CM. Q.F. VICKERS
M15	6/15	CM. MORTARS
M14	4/12	CM. HOWITZERS
M13	6/21	CM. MORTARS
M12	6/15	CM. HOWITZERS
M9	6/15	CM. HOWITZERS
M10	4/21	CM. MORTARS
1	2/24	CM. KRUPP GUNS
1B	4/12	CM. HOWITZERS
3	2/28 2/26 2/24 CM KRUPP 4/8·8 CM. Q.F. GUNS	
4	2/24	CM. KRUPP GUNS
6	2/28 2/26 2/24 1/21 1/15 CM KRUPP 1/15 CM NAVAL KRUPP	

GERMAN DEFENCES ON THE BELGIAN COAST.

1. 4·15-cm. anti-landing guns.
2. 24-cm. railway gun.
3. Aachen, 4·15-cm. guns.
4. Antwerpen, 4 10·5-cm. guns.
5. Aldenburg, 4 17-cm. guns.
6. Beseler, 4 15-cm. guns.
7. Cecilie, 4 15-cm. guns.
8. Tirpitz, 4 28-cm. guns.
9. Eylau, 4 8·8-cm. guns.
10. A.A. batteries.
11. Hindenburg, 4 28-cm. guns.
12. Friedrich, 4 8·8-cm. guns.
13. Irene, 33 15-cm. guns.
14. Preussen, 4 28-cm. guns.
15. 4 A.A. guns.
16. Schlesien, 4 17-cm. guns.
17. Deutschland, 4 38-cm. guns.
18. 3 A.A. guns.
19. Hannover, 4 28-cm. guns.
20. Gneisenau II., 4 17-cm. guns.
21. 2 8·8-cm. guns.
22. 4 A.A. guns.
23. Hertha, 4 21-cm. guns.
24. Hafen, 4 8·8-cm. guns.
25. Hessene, 4 28-cm. guns.
26. Sachsen, 4 17-cm. guns.
27. A.A. guns.
28. Kaiserin, 4 15-cm. guns.
29. Mittel, 4 10·5-cm. guns.
30. Groden, 4 18-cm. howitzers.
31. Wurtemburg, 4 10·5-cm. guns.
32. Ludendorff, 3 15-cm. guns.
33. Lübeck, 2 15-cm. guns.
34. Molen, 2 8·8-cm. & 4 10·5-cm. guns.
35. Molen, 2 15-cm. guns.
36. Friedrichsort, 4 17-cm. guns.
37. Kanal, 4 8·8-cm. guns.
38. A.A. guns.
39. Freya, 4 21-cm. guns.
40. Augusta, 3 15-cm. guns.
41. Kaiser Wilhelm II., 4 30·5-cm. guns
42. Hamburg, 4 10·5-cm. guns.
43. Braunschweig, 4 28-cm. guns.
44. Schleswig Holstein, 2 17-cm. guns.
45. Lekkerbek, 2 8·8-cm. guns.
46. A.A. guns.
47. Bremen, 4 10·5-cm. guns.
48. Schutzenest, 6 5-cm. guns.

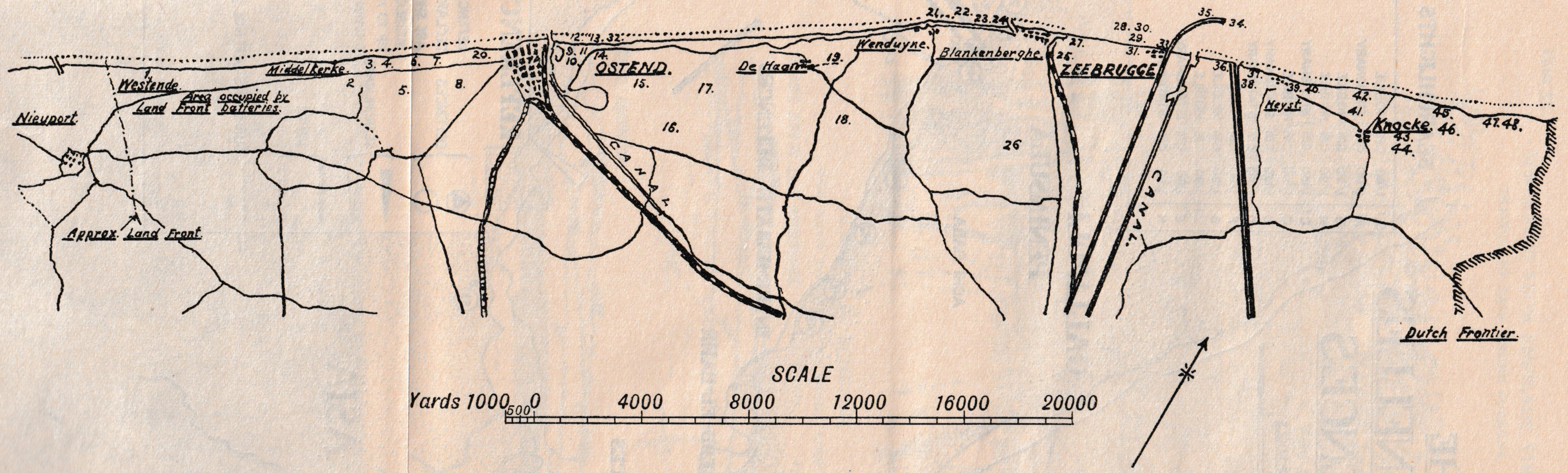


Plate 24.

EMPLACEMENT FOR GERMAN 38-CM. NAVAL GUN ON BELGIAN COAST.

DEUTSCHLAND BATTERY. SHOWING MAGAZINES.

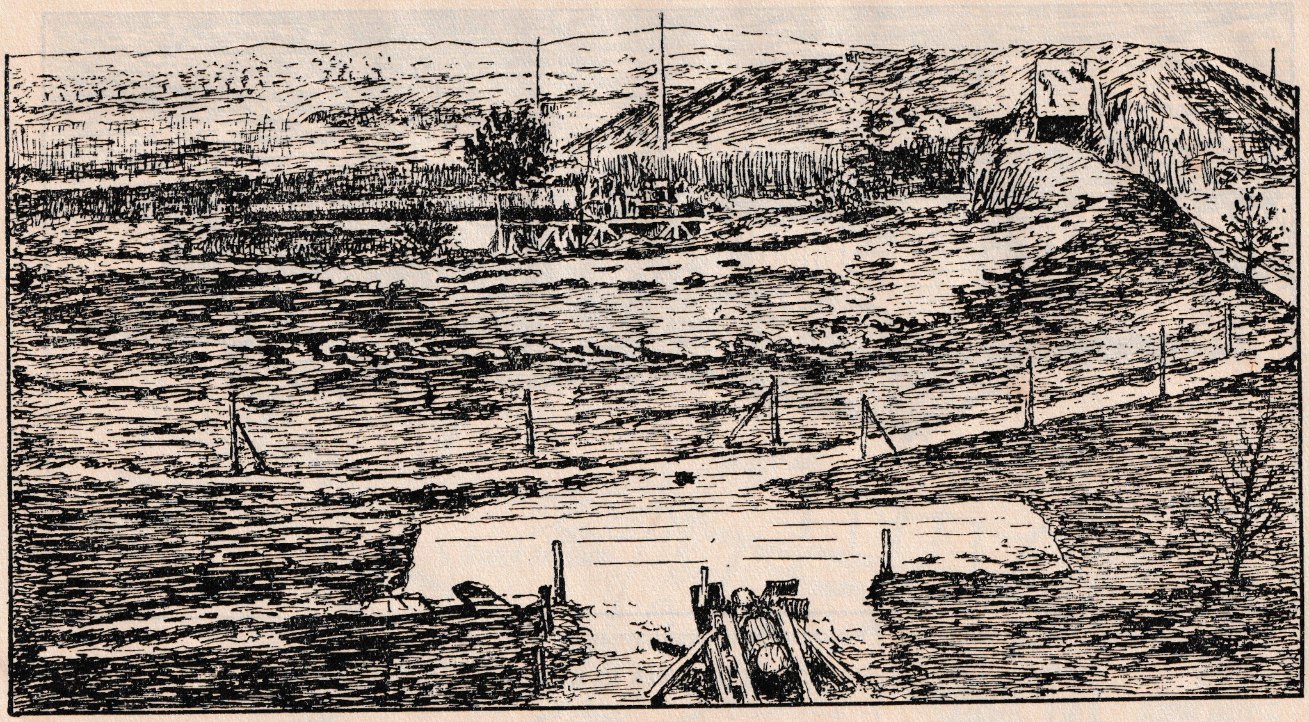
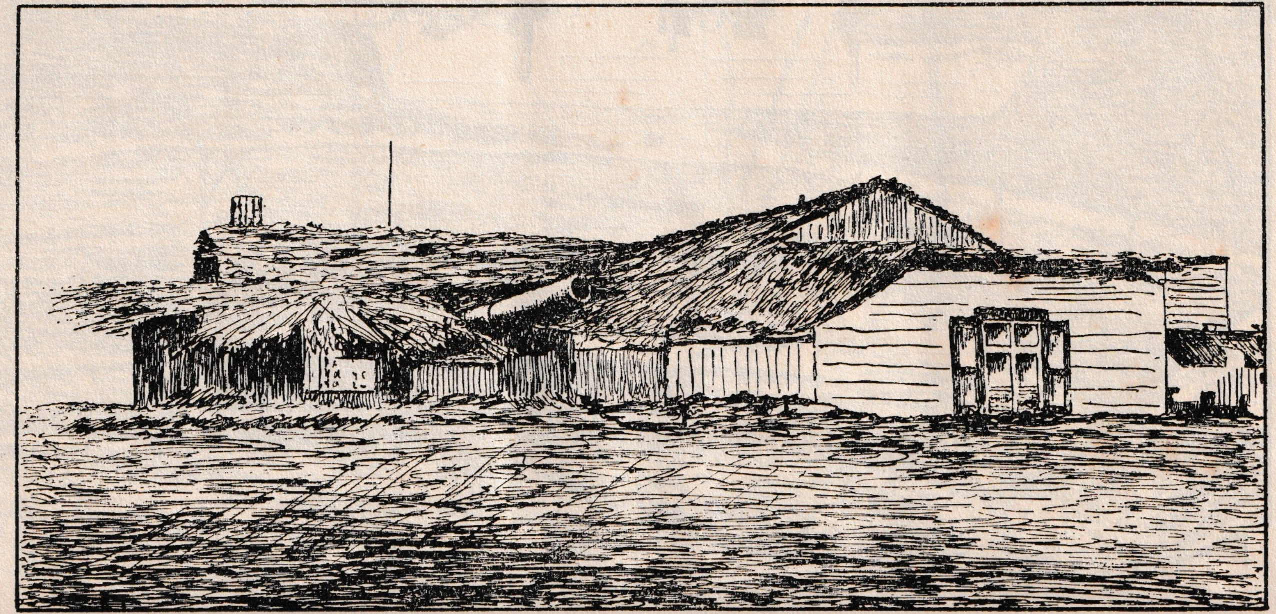


Plate 25.

EMPLACEMENT FOR GERMAN 17-CM. Q.F. GUN ON BELGIAN COAST.

OLDENBURG BATTERY. EMPLACEMENT DISGUISED AS A FARMHOUSE.

Plate 26.



PLAN OF ZEEBRUGGE HARBOUR.

SHOWING POSITIONS OF "VINDICTIVE" AND BLOCKSHIPS.

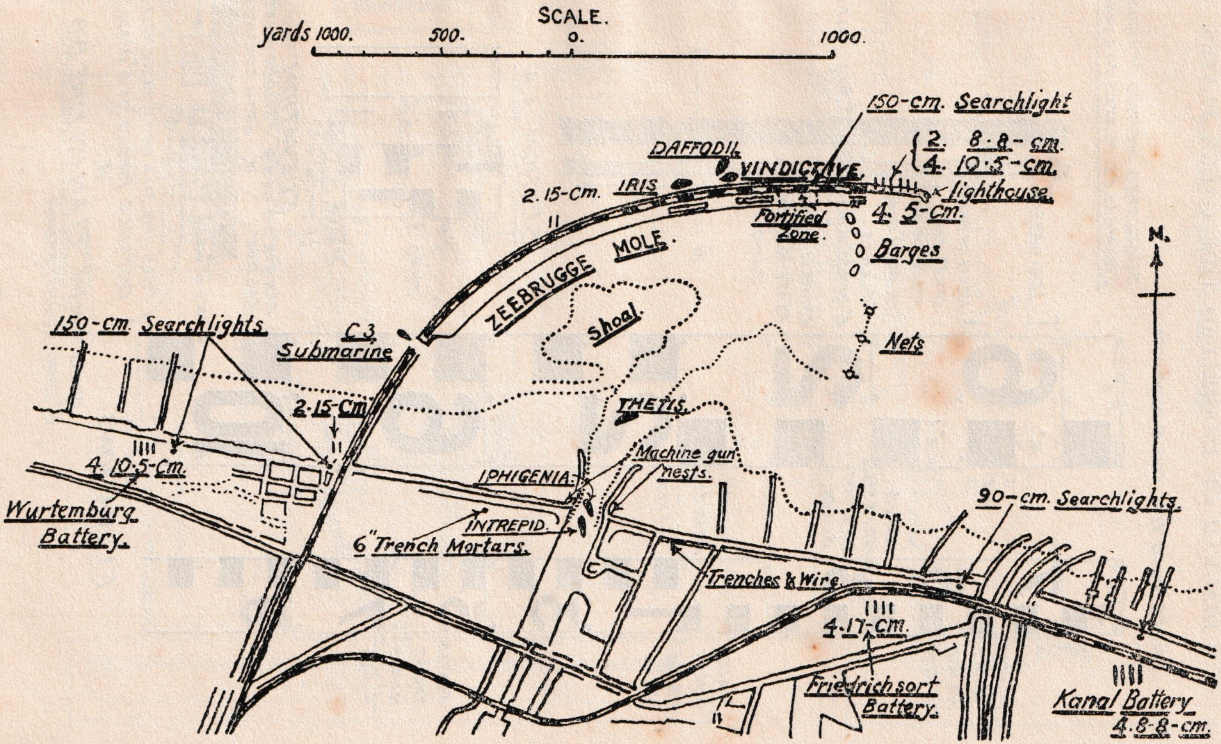
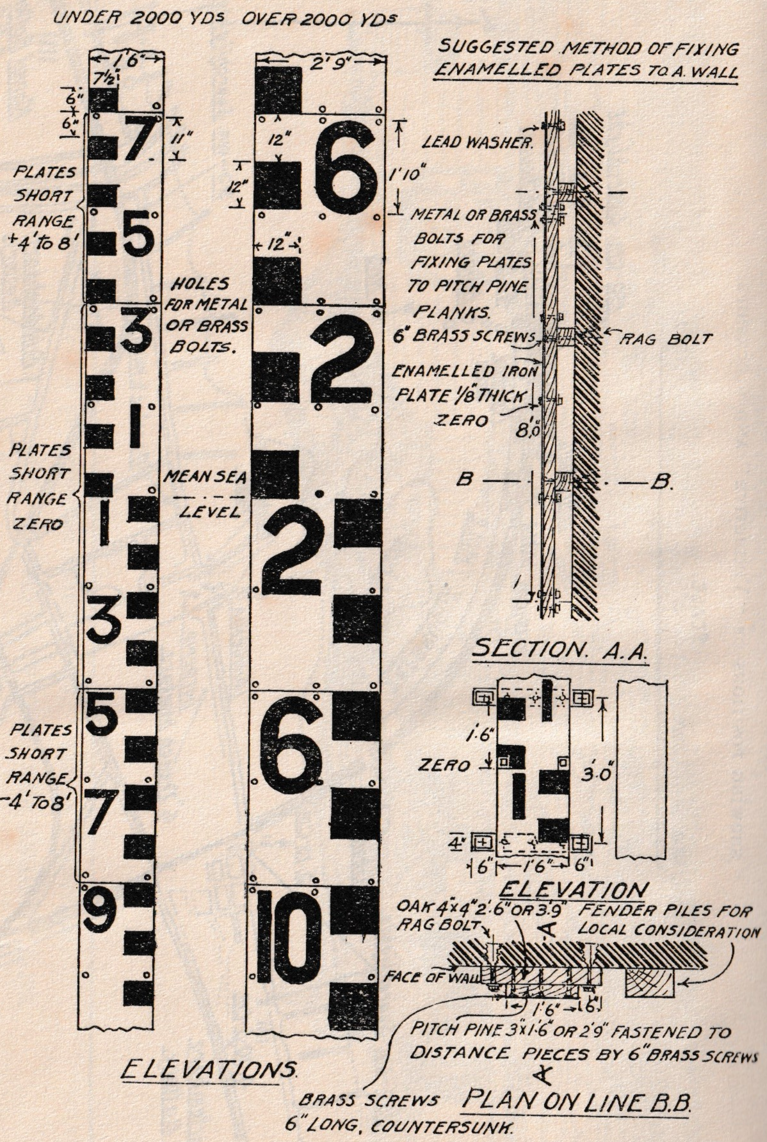
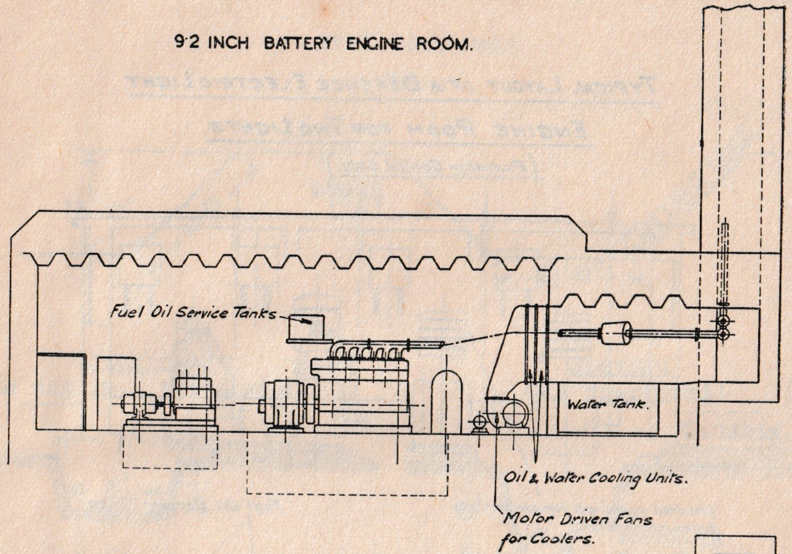


Plate 27.

DIAGRAM OF ENAMELLED TIDE GAUGE PLATES.



9·2 INCH BATTERY ENGINE ROOM.



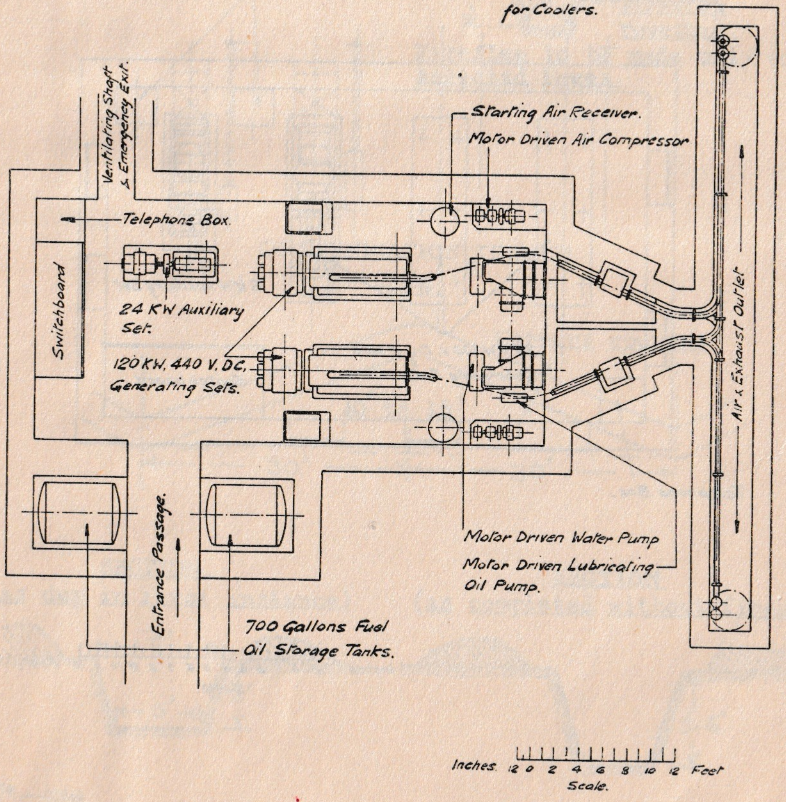
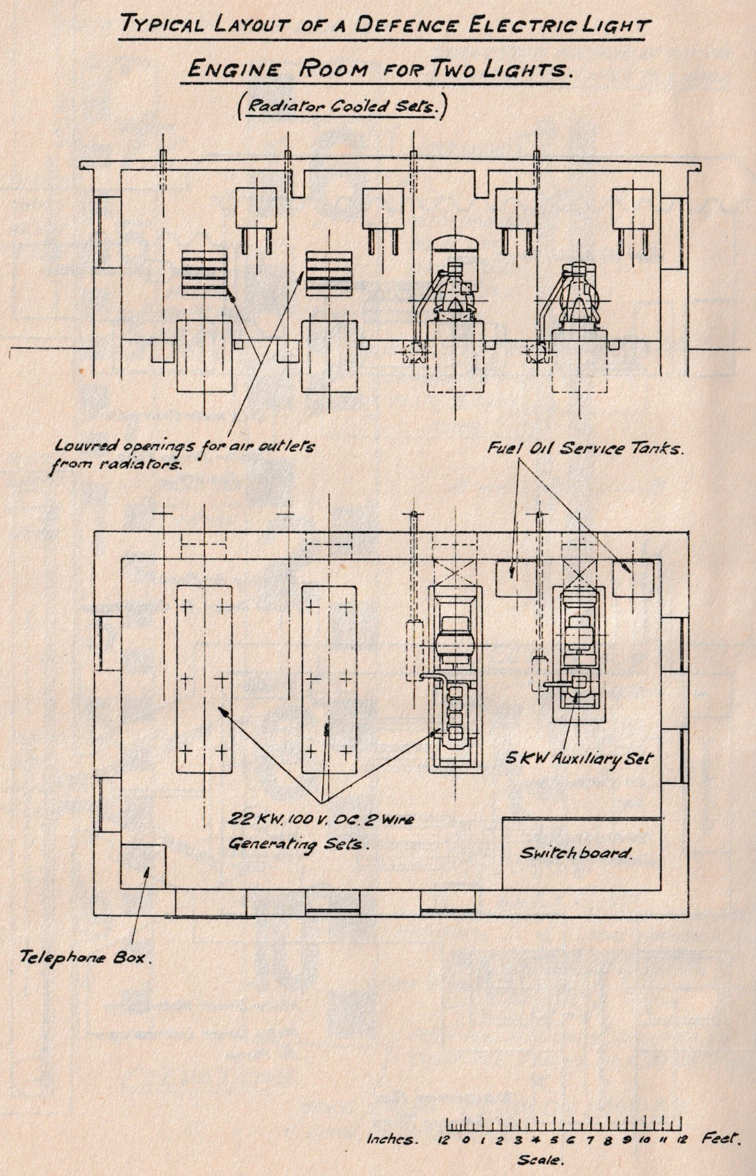
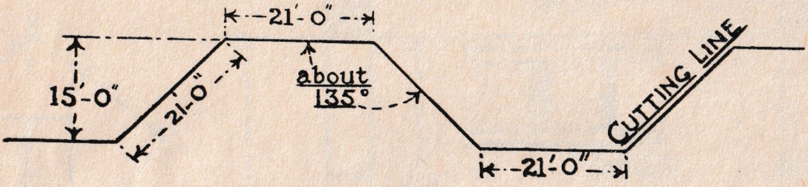


Plate 30.

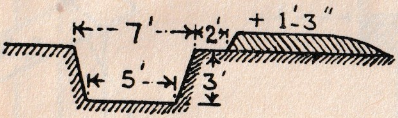

TYPICAL LAYOUT OF A DEFENCE ELECTRIC LIGHT
ENGINE ROOM FOR TWO LIGHTS.
(Radiator Cooled Sets.)
Louvred openings for air outlets from radiators.
Fuel Oil Service Tanks.
5 KW Auxiliary Set
22 KW. 100 V. DC. 2 Wire Generating Sets.
Switchboard.
Telephone Box.
Inches. 12 0 1 2 3 4 5 6 7 8 9 10 11 12 Feet.
Scale.

FIRE TRENCHES.

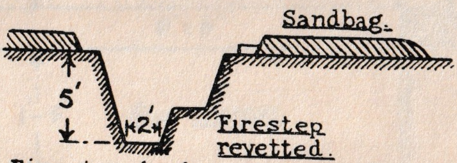
TRACE.



SECTION.
(as dug in first instance)



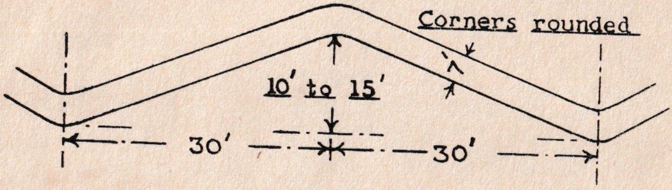
SECTION.
(as completed)



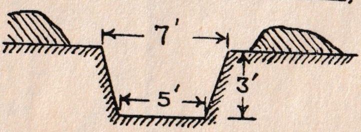
Firestep to be made only on selected faces.

COMMUNICATION TRENCH.

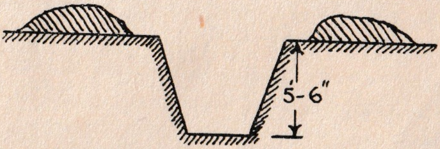
TRACE.



SECTION.
(as dug in first instance)

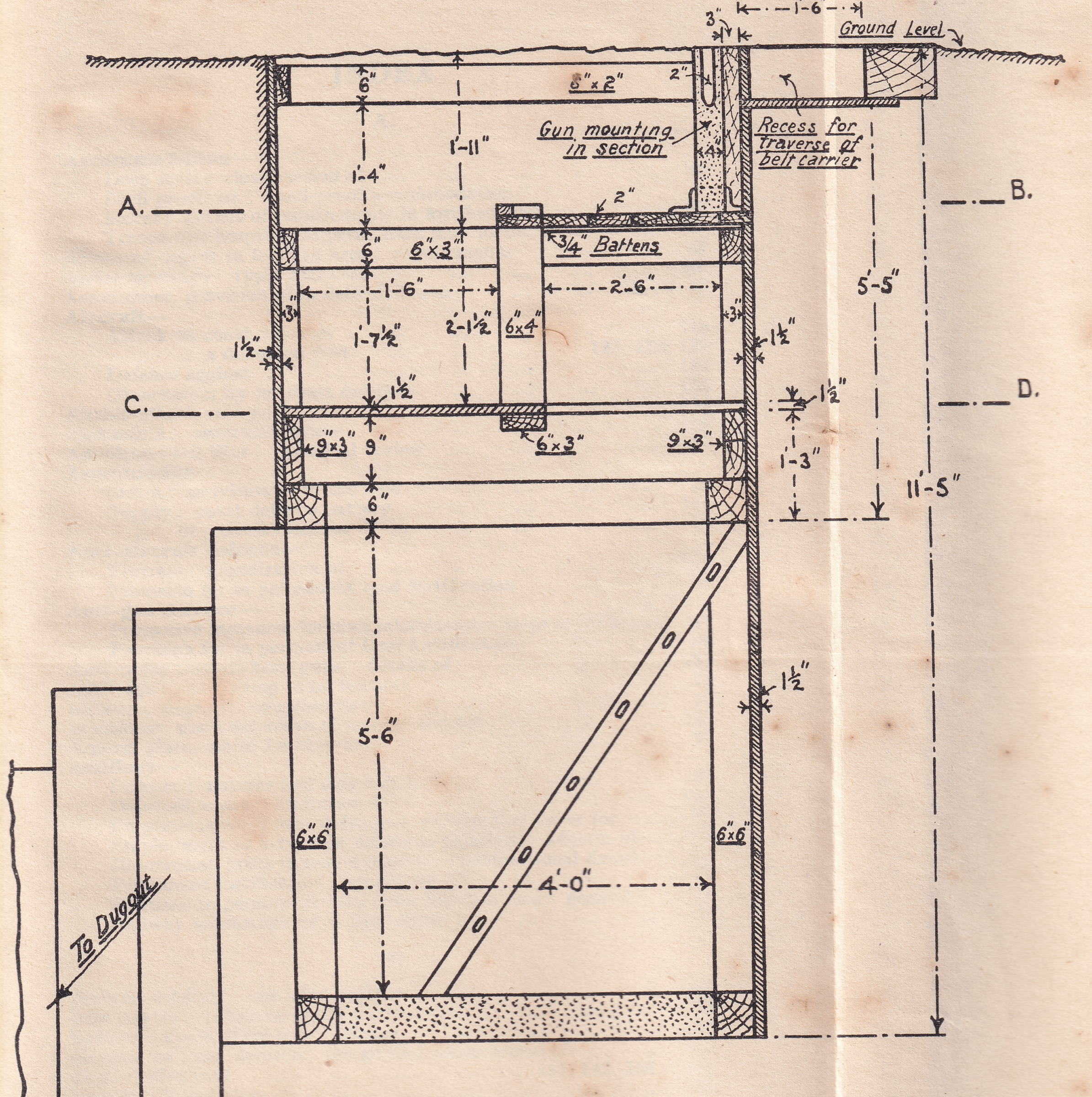


SECTION
(as completed without firestep.)

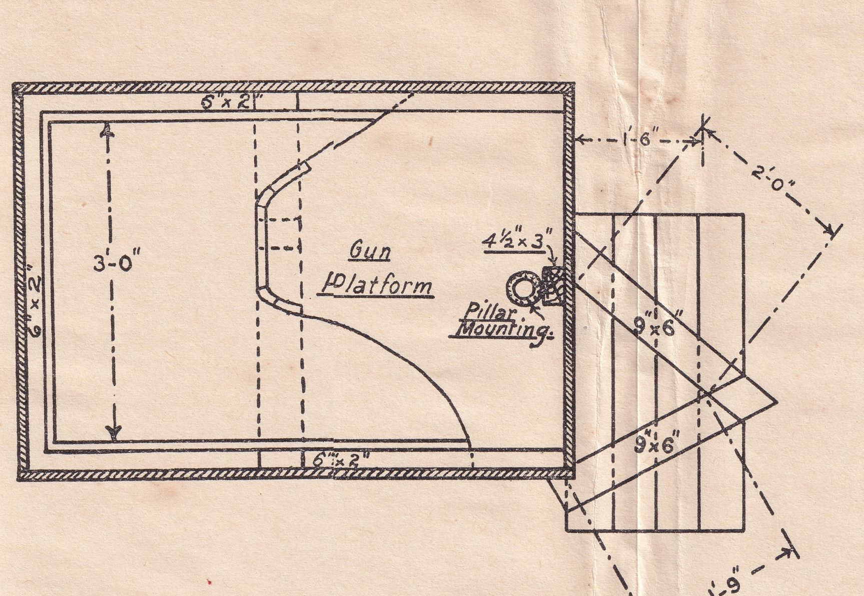


MACHINE GUN EMPLACEMENT (CHAMPAGNE TYPE).

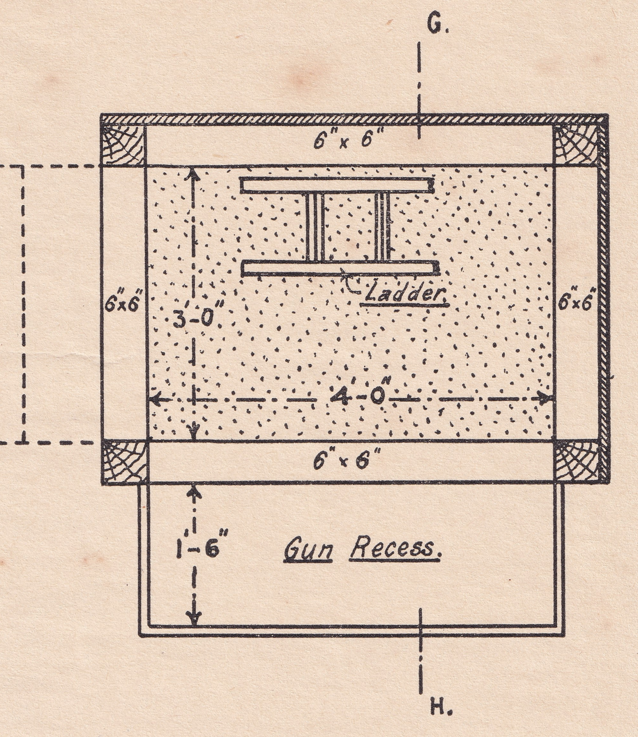
WITH INCLINED SHAFT TO DUG-OUT.



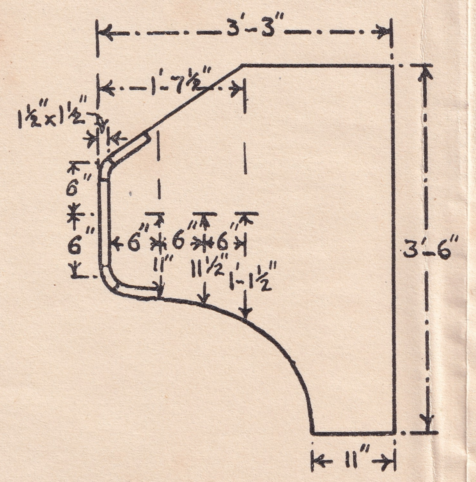
— SECTION E.F. —



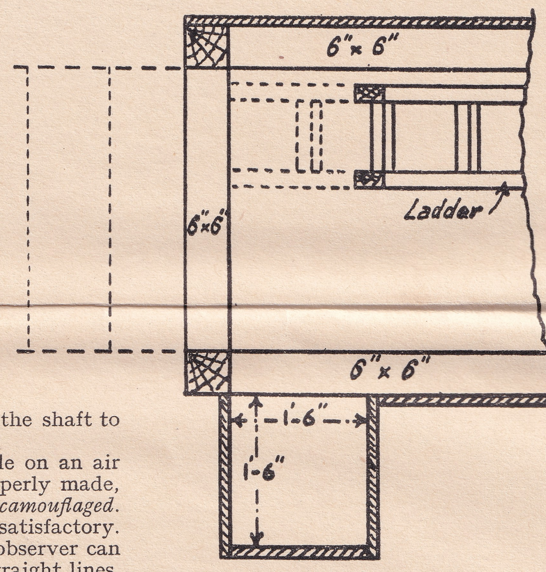
— SECTIONAL PLAN A.B. —



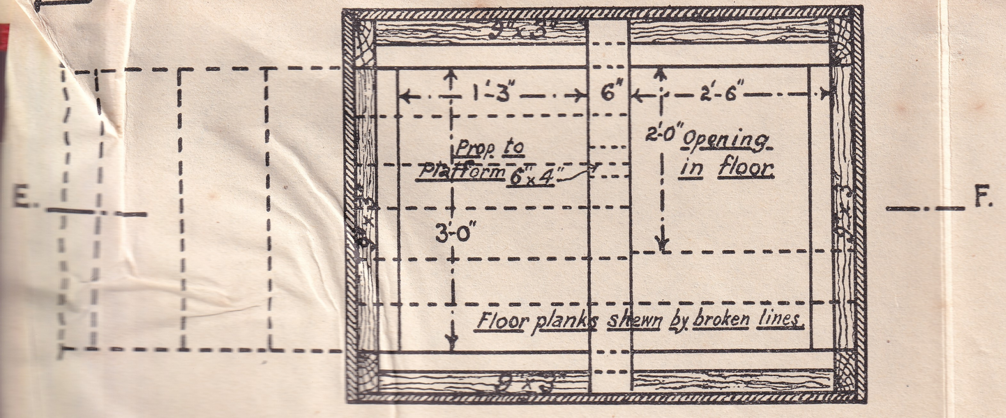
— PLAN AT BOTTOM OF SHAFT. —



— GUN PLATFORM. —



— SECTION G.H. —



— SECTIONAL PLAN C.D. —

NOTES.

1. The all-vertical and all-incline shafts have been found inferior as regards service of the gun and safety of the shaft to the combined vertical and inclined shaft shown in the Plate.

2. A shell hole has been found an unsatisfactory exit for a shaft; it is usually wet and easily discernible on an air photograph. A good piece of unbroken ground should be selected for the exit, and the emplacement properly made, with its opening as small as compatible with a traverse of 120° to 140°. The top of the emplacement should be *camouflaged*. Batten doors hinged to the sides and covered with camouflage string netting loosely applied have been found satisfactory. They are made to close together in such a way as to make a pent roof with about 6-in. rise, in order that an observer can look through the netting without opening the doors. Bunches of scrym can be tied on the edges to break up straight lines. Sliding panels, if preferred, can be used instead.

3. The hole in the emplacement floor was originally fitted with a trap-door. This was considered objectionable, as a wounded man might fall on it and prevent it being opened from below. A roll-top *gas blanket* should be placed over it: the gun table prevents a man falling down the shaft, but does not get in the way of easy access by the ladder.

A second gas blanket can be fitted at the top of the incline, and a brazier kept ready to light at the bottom of the vertical to keep out or clear gas that has penetrated.

4. A pillar mounting for a Vickers to replace the tripod can be made and screwed by brackets to the front of the emplacement as shown. This necessitates a recess 9 in in height to allow of the traverse of the belt carrier. It does not prevent the use of the tripod if this becomes necessary.

An all-round fire pillar mounting to stand in the centre of the emplacement necessitates a larger emplacement about 6 ft. × 6 ft. It might be suitable for special cases.

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Major R.E.
O.C. 571
Army Field Company R.E.

DEVON & CORNWALL
No.
23 OCT 1940
571 ARMY FIELD COY. R.E.